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Anatomical Studies on Some Leguminous Leaves with Special Reference to the Vascular System in Petioles and Rachises.*

By

Shunji WATARI.

With 4 Plates and 51 Text-Figures.

Introduction.

The petiole and rachis of dicotyledonous species have hitherto been studied, both anatomically and morphologically, by many investigators. The vascular anatomy, however, has been undertaken by comparatively few investigators, most of whom gave consideration merely to the topographical arrangement of bundles in one or at most a few transverse sections through a region of the leaf; thus our knowledge concerning the complete vascular system in this organ is at present somewhat meagre. With the idea of throwing fresh light on this subject,—hitherto so inadequately dealt with—the writer commenced, in December 1930, a study on the vascular anatomy of the petiole and rachis of leguminous leaves. The reasons why the leguminous leaves are selected for the purpose of the present investigation are (1) that, in this family, according to the results of previous investigators, one may expect to find varieties of the vascular system in this organ by further observation; (2) that it seems to be convenient to compare the various leaf-types from the vascular-anatomical view points; and (3) that, a considerable number of species can easily be collected in our country.

§ Historical.

In the following lines, I shall give a brief account of the results of some of the important works previously undertaken concerning the vascular anatomy of the leaves, especially, of those of *Leguminosæ*.

First of all, we can point to the work of GREW (1682), who showed the transverse section of petioles of nine species (e. g. *Verbascum*). MIRBEL (1815) described the vascular bundles in petioles, disposed in the form of a cylinder or a

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gutter in most species, such a disposition of the bundles preventing the flexion of the petiole. According to A. P. DE CANDOLLE (1827) the petiole usually contains parallel bundles, but otherwise the bundles are generally separated from one another at the base, approaching each other again at the higher part. DUTROCHET (1837) described the swollen part of the petiole of *Phaseolus*, *Mimosa pudica*, and *Hedysarum strabiliferum*, giving the figures in the latter two species (Pl. 16, figs. 3 and 4).

In the memorial work of NÄGELI (1858), the vascular course of the various plants was treated, dividing them into many types, this division being based mainly on the phyllotaxy and the number of leaf traces. In his work, some leguminous plants such as *Erythrina crista-galli*, *Lupinus Lehmani*, *L. luteus*, *Medicago sativa*, many species of *Lathyrus*, and *Phaseolus vulgaris* were treated, though the structure of the petiole and rachis was not given. FRANK (1864), TRÉCUL (1866 and 1867) studied the vascular anatomy of some dicotyledonous petioles, and C. DE CANDOLLE, in 'Théorie de la feuille' (1868), showed some diagrams representing the transverse section through the middle of the petiole. Also DE LANESSAN (1874) described some anomalous disposition of the petiolar bundles. The petioles of leguminous plants however were not treated by these authors.

SCHWENDENER, in his "Das mechanisch Princip in anatomischen Bau der Monocotylen" (1874), stated that many petioles as well as stems, showed a structure suited to withstand flexion, *Ricinus communis*, *Lupinus floribunda*, *Aralia japonica*, etc. being cited as examples explaining his principle. DE BARY (1877) writing in his "Vergleichende Anatomie" on the vascular system in the petiole, stated that "Grössere Blätter, z. B. von *Leguminosen*, *Umbelliferen*, liefern für diese Verhältnisse mannichfache,". In 1879, C. DE CANDOLLE again published a work on the comparative anatomy of leaves, and divided the disposition of petiolar bundles in transverse section into two different types; the "système ouvert" and the "système fermé".

VAN TIEGHEM, in his "Traité de botanique" (1884), treated the disposition of bundles in the petiole, stating that these bundles were nearly always disposed in the form of an open arc; and he added, "le faisceau médian et inférieur de l'arc est aussi d'ordinaire le plus développé et les autres vont diminuant de grandeur de chaque côté à mesure qu'ils s'éloignent du premier, les plus petits occupant les bords de l'arc; des faisceaux plus petits alternent parfois avec de plus gros". Moreover, he found cases in which the bundles were disposed in a complete ring or in a few smaller separated ones. Also he reported,

"l'anneau est surmonté de deux faisceaux latéraux symétriques" in *Cytisus*, *Robinia*, *Wistaria*, and some others.

In 1887, ACQUA divided the dicotyledons into thirteen groups instancing as characteristics, the number and arrangement of the foliar traces, and the mode of anastomosing in the basal and slender parts of the petiole. In his work, many leguminous leaves including various phyllodes of *Acacia* were treated and classified into seven distinct types, four of which were considered as special types of *Leguminosæ*. According to COL, the same classification was chosen in the work of GUILLARD (1870). AVETTA (1884) examined *Pueraria Thunbergiana* BENTH, illustrating the condition of foliar strands and the basal part of the petiole in which the medullary bundles were shown in the transverse section through the middle of the pulvinus. To my regret, I could not get the opportunity of seeing the contents of the work of PLITT (1886) on the vascular anatomy of dicotyledonous petiole.

The thèse of PETIT (1887) is one of the most important works on the fibro-vascular system of dicotyledonous petioles, investigated from the comparative-anatomical and taxonomical points of view, and including about sixty species of leguminous plants. Not only the fibro-vascular system of the petiole, but also the hair, the external membrane of the epidermal cell, collenchym and sclerenchym, crystals, etc., were investigated for the purpose of his study. According to him, the fibro-vascular system in the petiole was roughly divided into "*types simples*" and "*types complexes*", the former including four different types and the latter eight types. He termed the transverse section through the base of the petiole as "*initial*" and that through the top of petiole as "*caractéristique*". BOUYGUES (1902) published an important study on the development of the anomalous petiolar bundles. The disposition of bundles in the petiole was divided into two main types: "pétioles présentant un système libéro-ligneux en cercle fermé" and "pétioles présentant un système libéro-ligneux en arc ouvert". The structures of bundles, especially of "*faisceaux concentriques*" and "*faisceaux rayonnés*", were closely examined many species of *Cruciferae* and *Rosaceae* being studied, and among the *Leguminosae* the whole vascular system in the petioles of *Cercis siliquastrum* and *Bauhinia glandiflora* was somewhat minutely described in connection with these anomalous bundles.

COL (1904) investigated many leaves of dicotyledons, and divided the conditions in these petioles, from the view point of the arrangement of bundles, into "*normal*" and "*anormal*". His definition on the "*normal*" arrangement

of petiolar bundles is "la disposition du système libéroligneux sur un arc postérieurs continu ou divisé en faisceaux", while "Si cet arc, se recourbe sur lui-même, les faisceaux placés au-dessus de l'arc inférieur (postérieur) seront donc dans un trajet plus ou moins anormal". Among the leguminous species, *Bauhinia racemosa*, *Cercis siliquastrum*, *Cytisus Laburnum*, *Albizzia lophantha*, *A. Mollugo*, and *A. anthelimitytica*, were pointed out as representing the more or less "anormal" disposition of bundles. In 1912, PETERS investigated systematic-anatomically many phyllodes of *Acacia*, taking as characteristics, the structure of the epidermal and subepidermal system, the assimilatory system, the mechanical system, and the pith, and he classified the phyllodes external-morphologically into "*Plattentypus*", "*Binsentypus*", and "*Übergangstypus*". In regard to the disposition of vascular bundles, he briefly stated that they were arranged on the periphery of the pith and, as a natural consequence, they were arranged in two rows in "*Plattentypus*" and in radial disposition in "*Binsentypus*". In 1913, the course and distribution of the petiolar bundles for each leaflet of compound leaves were investigated, both from the anatomical and physiological points of view, by GERRESHEIM (1913) and RIPPEL (1913). The former investigated the pinnate leaves and divided them into ten types, the classification being determined by the number of foliar traces, the mode of connection of bundles at the base of the petiole, and the number of traces for a leaflet. The vascular system in *Vicia Faba* was chosen as the fifth type. The same investigation was made in reference to the palmate compound leaves by RIPPEL, who divided them into eight types, *Trifolium elegans* being represented as the seventh. SINNOT (1914) maintained the taxonomical and phylogenetical importance of the number of gaps in regard to a leaf, and the nodal forms were divided into three types; "*unilacunar*", "*trilacunar*", and "*multilacunar*". WINTER (1932), in his investigation on the vascular system of *Medicago sativa*, described somewhat precisely the foliar traces and vascular course in the petiole and rachis.

In regard then to these above mentioned works, we see that whereas numerous investigations have been undertaken with reference to the whole vascular system of the leaf, chiefly by ACQUA (1887), PETIT (1889), COL (1904), GERRESHEIM (1913), and RIPPEL (1913), yet the many different leguminous species were treated only by the two first named investigators, and that in an unsatisfactory manner. The conclusion formed by these investigators on the vascular system will be again stated in later paragraphs, when they will be compared with the results of my own investigations.

§ Methods and Materials.

For the purpose of tracing the vascular system in the petiole, different methods were used as necessity arose. In cases where the materials were very minute or feeble as seen in young or very minute petiolules of the leaflets, serial paraffin sections were preferred. In many cases, however, serial free hand sections were carried out. Occasionally concentrated hydrochloric acid and phloroglucinol were used in order to bring out the vascular bundles, and sections were temporarily mounted in glycerin.

The '*agar method*'—as I call it—was very effective for the purpose of preparations. This method,—because by it the sections could be prepared from both preserved and fresh materials—, has an obvious advantage in the fact that it permits of the examination of a large amount of materials with the least expenditure of time. GRAVIS (1889 and 1897) described a method of fixing the paraffin or celloidin sections to the slide glass, using respectively 0.1 and 0.75 per cent aqueous solution of agar-agar as fixative. Though some useful hints were obtained from his agar method, 0.75 per cent agar-agar is rather too dilute for the free hand sections of leguminous leaves, chiefly because the sections cut by hand are necessarily thicker than those cut by the microtome, moreover, the sections through the pulvinus, generally found at the basal part of the petiole in this family, tend to warp owing to the special structure in this region, and according to my experience, 1.5–3 per cent agar-agar solution seems suitable for these sections. The following is my method:—a proper quantity of agar-agar solution in a little glass bottle is immersed in the hot-water-bath which is kept warm by the fine flame of a BUNSEN's burner; a few drops of the solution are striped with a fine brush on the slide glass and on this sections are arranged in succession, by means of a fine pinset. This process must be carried on quickly before the agar-agar solution coagulates; but if the coagulation occurs too fast, it can be remedied by warming the slide glass. Repeating this treatment, 40–60 sections or more in regular order can easily be arranged on a slide-glass. The slide-glass is then immersed in absolute alcohol, passing through concentrations of increasing strength—50, 75, and 95 per cent. In staining, the combination of safranin and light green in ordinary schedule was selected in the present study, and after staining the preparation was cleared in xylol and finally mounted in Canada balsam.

The dissection of the organs under investigation was to some extent used to supplement the methods stated above. The cortical part of the organs was

carefully peeled off and the materials thus dissected were cleared in xylol after being dehydrated by alcohol. Many details of importance were able to be observed in this cleared preparation.

Most of the materials used in this study are native in Japan, and were collected mostly near Tokyo; some, both wild and cultivated, were collected in the Bonin Islands. Moreover some species from Formosa and some exotic species cultivated in the Botanic Garden of Tokyo Imperial University were also examined.

In the present study of leguminous leaves, the writer examined the following 133 species.

MIMOSOIDEÆ.

INGEÆ

- Pithecolobium dulce* BENTH.
P. Saman BENTH.
Albizia Julibrissin DURAZZ.
A. Lebbek BENTH.

ACACIÆ

- Acacia arabica* WILLD.
A. confusa MERR.
A. sphærocephala CHAM. et SCHLECHT.
A. villosa WILLD.

EUMIMOSEÆ

- Mimosa myriophylla* BONG.
M. pudica L.
M. Spegazzinii PIROTTA

ADENANTHEREÆ

- Adenantha microperma* TEIJSM. et BINN.

CÆSALPINIOIDEÆ.

DIMORPHANDREÆ

- Erythrophleum guineense* G. DON

AMHERSTIÆ

- Saraca indica* L.
Amherstia nobilis WALL.
Tamarindus indica L.

BAUHINIÆ

- Cercis canadensis* L.
C. chinensis BUNGE
Bauhinia acuminata L.
B. alba BUCH.-HAM.
B. candicans BENTH.
B. Galpinii N. E. BR.
B. japonica MAXIM.
B. purpurea L.

CASSIÆ

- Cassia Fistula* L.
C. marylandica L.
C. mimosoides L. var. *nomame* MAKINO
C. sulphurea DC.
C. Tora L.
C. torosa CAV.
Ceratonia Siliqua L.

EUCÆSALPINIÆ

- Gleditschia japonica* MIQ. (*G. horrida* MAKINO)
Hæmatoxylon campechianum L.
Poinciana regia BOJ.
Cæsalpinia japonica SIEB. et ZUCC.
C. Bonducella FLEM.
C. Sappan L.

PAPILIONATÆ.

SOPHOREÆ

- Ormosia formosana* KANEHIRA
Sophora angustifolia SIEB. et ZUCC.
Styphnolobium japonicum SCHOTT (*Sophora japonica* L.)
Cladrastis lutea RAFIN.
Platyosprion platycarpum MAXIM. (*Cladrastis platycarpa* MAKINO)
Maackia amurensis RUPR. et MAXIM. var. *Buergeri* SCHNEID. (*Cladrastis amurensis* BENTH. var. *Buergeri* MAXIM.)

PODARYLIÆ

- Thermopsis fabacea* DC.
Baptisia australis R. BR.

GENISTEÆ

- Crotalaria sessiliflora* L.
C. usaramoensis E. G. BAKER

Lupinus luteus L.
L. hirsutus L.
Genista anglica L.
G. germanica WILLD.
G. pilosa L.
Laburnum vulgare J. PRESL.
Ulex europæus L.
Cytisus Scoparius LINK.

TRIFOLIEÆ

Medicago denticulata WILLD.
M. sativa L.
Melilotus suaveolens LEDEB.
Trifolium Lupinaster L.
T. repens L.
T. pratense L.

LOTEÆ

Lotus corniculatus L. var. *japonicus* REGEL

GALEGEÆ

Indigofera incarnata NAKAI (*I. decora* LINDL.)
I. Kirilowii MAXIM.
I. pseudo-tinctoria MATSUM.
I. Dosua BUCH.-HAM.
Amorpha fruticosa L.
Tephrosia candida DC.
Millettia reticulata BENTH.
M. taiwaniana HAYATA
Wistaria floribunda DC.
W. japonica SIEB. et ZUCC. (*Millettia japonica*
 A. GRAY)
W. sinensis DC.
W. venusta REHDER et WILSON
Robinia hispida L.
R. pseudacacia L.
Caragana Chamlagu LAM.
Astragalus reflexistipulus MIQ.
A. adsurgens PALL.
A. sinicus L.
Glycyrrhiza dubia BERNH.
G. echinata L.
G. foetida DESF.

HEDYSAREÆ

Aeschynomene indica L.
Arachis hypogæa L.
Desmodium gyrans DC.
D. caudatum DC.
D. Oldhami OLIV.
D. podocarpum DC. var. *indicum* MAXIM.
D. racemosum DC. (*D. japonicum* MIQ.)

Lespedeza Buergeri MIQ.
L. cuneata G. DON
L. nikkoensis NAKAI
L. pilosa SIEB. et ZUCC.
L. serpens NAKAI
L. tomentosa SIEB.
Kummerowia striata SCHINDLER (*Lespedeza*
striata HOOKER et ARNOTT.)

DALBERGIEÆ

Dalbergia Sissoo ROXB.
Derris elliptica BENTH.
Pongamia glabra VENT.
Pterocarpus indicus WILLD.
Euchresta japonica BENTH.

VICIEÆ

Vicia bifolia NAKAI
V. Faba L.
V. hirsuta KOCH
V. nipponica MATSUM. var. *typica* NAKAI
Vicia sativa L.
V. tetrasperma MOENCH.
V. unijuga AL. BR.
Lathyrus Davidii HANCE
L. maritimus BIGEL. var. *glaber* FERNALD
L. palustris L. var. *linearifolius* SER.
L. vernus KUNTH.
Pisum sativum L.

PHASEOLEÆ

Cilioria ternata L.
Amphicarpæa japonica B. FEDTSCH.
Dumasia truncata SIEB. et ZUCC.
Glycine Soja BENTH.
G. ussuriensis REG. et MAACK
Erythrina crista-galli L.
E. indica LAM.
Apios Fortunei MAXIM.
Mucuna ferruginea MATSUM.
M. Toyoshimai NAKAI
Pueraria Thunbergiana BENTH.
Canavalia ensiformis DC.
C. lineata DC.
Rhynchosia volubilis LOUR.
Phaseolus angularis W. F. WIGHT (*Dolichos*
angularis WILLD.)
P. multiflorus WILLD.
Vigna sinensis ENDL.
V. sinensis ENDL. var. *Catiang* NAKAI
Dolichos Lablab L.

Some notes on terminology:—The materials used in this study were mostly in maturity, though young specimens were sometimes chosen, with the special intention of making it easy to understand the process and completion of development, as shown in mature leaves. The sectioning was always carried on from the nodal region of stem to the higher part of the leaf through the leaf-base, so that in comparing the sections, the one cut nearer the top of the leaf is called '*higher*' than that cut nearer the leaf-base. The figures of transverse sections in the present study are drawn with a drawing apparatus, as seen from the lower side. As for the surfaces of a leaf, those sides usually known as the upper (adaxial) and the lower (abaxial), are here called the '*ventral*' and the '*dorsal*' sides respectively. In treating the vascular system in the node, leaf-base, petiole, and rachis, the latter three of which are termed '*phyllopodium*' by BOWER (1889-1890), I use some special terms for several parts of the leaf-organ in order to facilitate description. It is preferable, from the vascular anatomical point of view, to divide the main rachis into two parts, the one, where the pinnae are attached, being here termed '*nodule*' because it is comparable in its nature to the node in the stem, and the other between nodules being termed '*internodule*' because it is comparable to the internode in the stem.¹⁾ The lanceolate or subulate small body between the highest pair of leaflets which is found in even-pinnate or bipinnate leaves is here named the '*terminal appendage*.' In many species, having more or less conspicuous ridges running along the slender part of the petiole and internodes, there is found, on each ridge, a single (sometimes but rarely more than one) small bundle which usually takes a somewhat independent position from the arrangement of the other bundles through the petiole and internodes. PETIT (1887) called these bundles, ".....surmonté de *deux petits faisceaux*" or "*deux faisceaux latéro-supérieurs*", ACQUA (1887) used the term "*una cerchia con cordoni corticali*", and VAN TIEGHEM (1884), "*l'anneau est surmonté de deux faisceaux latéraux symétriques*". Also such bundles were called, by SOLEREDER (1899) "*.....je ein rindenständiges in den beiden Kanten des Blattstiels*". It seems there is no adequate term for expressing these bundles, so in the present study I shall call them '*ridge bundles*'.

1) GERRESHEIM (1913) named '*Spindelknoten*' and '*Spindelinternodium*' respectively what I called here '*nodule*' and '*internodule*'.

PART I. DETAILED DESCRIPTIONS.

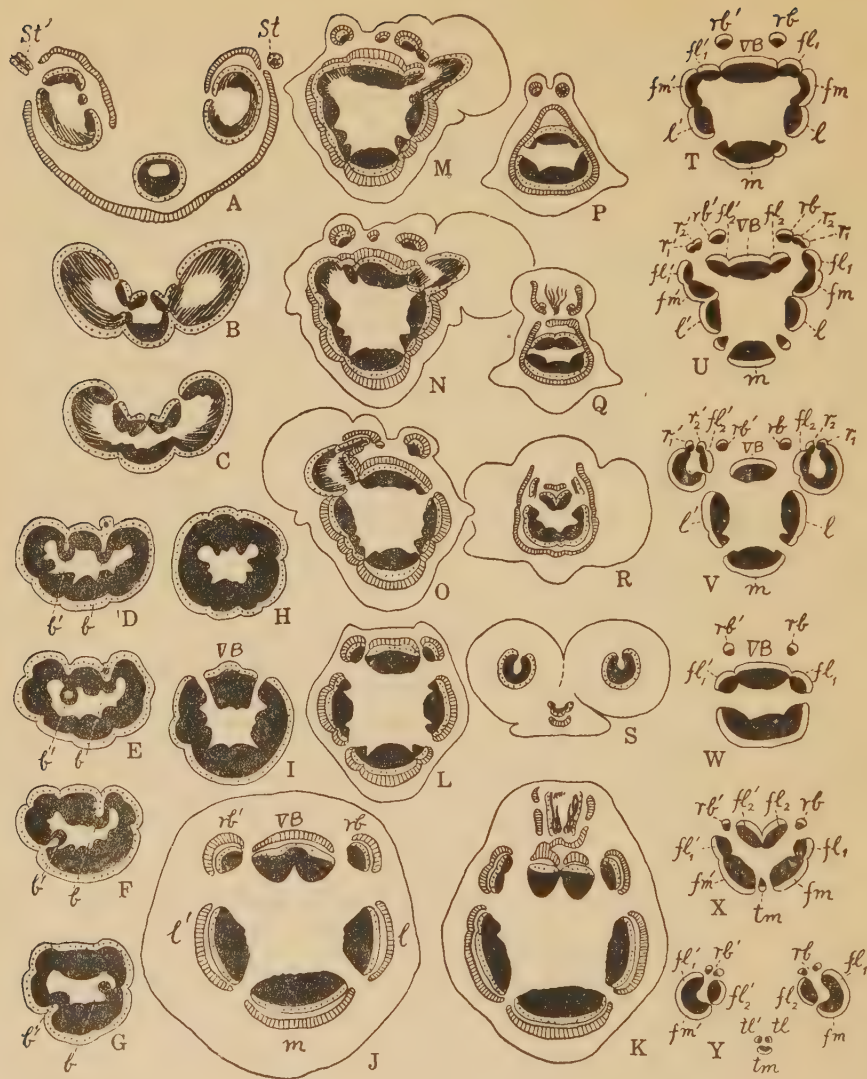
A. MIMOSOIDEÆ.

[1] INGEÆ.

Albizzia Julibrissin DURAZZ. [Text-fig. 1, A-Y; and Pl. VII, fig. 33]. The even-bipinnate leaf with 6-11 pairs of pinnae consisting of numerous leaflets, is provided with a glandular process both on the ventral side of the lower portion of the petiole, and on the ventral side of the highest nodule of the main rachis. Three foliar traces which come out from their own gaps of the stem, enter the base of the pulvinus, after a single stipular fascicle has left the outer lateral side of each lateral trace; each trace then becomes a small ringlet, its ventral portion being composed of both margins of the foliar trace (Text-fig. 1, A).¹⁾ Meanwhile, three ringlets fuse, side by side, to form a continuous ring (Text-fig. 1, B-H); therefore the ventral portion of this ring is composed of the marginal portions of three foliar traces. In the course of this process, small fascicles (indicated by *b* and *b'* in Text-fig. 1, D-G) often detach themselves from the two ventral portions of this ring, and are inserted into the lateral-dorsal portion; but, eventually, they form a continuous ring in the middle of the pulvinus. At the transitional region between the pulvinus and the slender part of the petiole, the continuous ring is separated into a large ventral bundle *VB* and a deeply-curved dorsal arc (Text-fig. 1, I). Thus, though three foliar traces lose their individuality by their fusion in the pulvinus, it may be said that the ventral bundle consists of the marginal portion of the original three foliar traces. A pair of ridge bundles *rb* and *rb'* branches out from each end of the arc mentioned above, which in turn is soon divided into three segments (*m*, *l*, *l'*) nearly proportional to the original three foliar traces (Text-fig. 1, J); so that the part where the ridge bundles leave corresponds to that of the stipular trace. In the transverse section through the middle of the slender part of the petiole (Text-fig. 1, L; and Pl. VII, fig. 33),²⁾

1) ".....des petits fascicules libériens placés sur la face antérieure du bois" in the lateral foliar traces on *Albizzia Mollugo* mentioned by COL (1904; p. 113 and Fig. XVIII, 3.) seem to represent the initial stage of this ringlet-formation.

2) Writing on the fibro-vascular system of this species, PETIT (1887; p. 68, 69 and Pl. IV, fig. 23; *Acacia Julibrissin* WILLD.) described a flattened ring at the "initiale" which becomes a complete circle at the higher part of the petiole, all the petiolar bundles being fused into a continuous ring, through the whole length of the petiole, after the ridge bundles have separated.



Text-fig. 1.¹⁾ *Albizzia Julibrissin* (A-Y, $\times 12$): A-K, pet. bas.; H, pet. mid.; M-O, a nod.; T-V, diagrammatic representation of the condition in a lower nod.; W-Y, that in the highest nod. Other explanation in text.

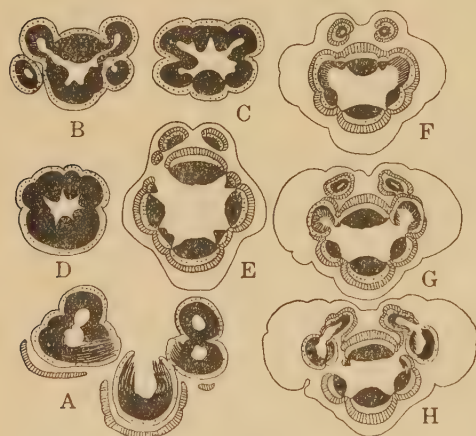
1) In the explanation of this and the succeeding figures, those showing the position are of transverse section and the following abbreviations are adopted. pet.=petiole or petiolar, pulv.=pulvinus, nod(s).=nodule(s), internod(s).=internodule(s), bas.=base, mid.=middle, black=xylem, dotted=phloem, lined=fibrous sheath.

there are four bundles, nearly equal in size and in circular arrangement, and in many cases a small bundle is segmented, from the margins of each bundle except the ventral one. A pair of ridge bundles which are situated just outside the circle, gradually migrate to the ridges of the petiole, which gradually becomes prominent at the higher part. Such a disposition of the bundles is seen through nearly the whole length of the slender part of the petiole; that is, an actual separation and anastomose of the bundles does not occur, except the vascular supply for the glandular processes which arises from the middle portion of the ventral bundle at the lower part of the petiole (Text-fig. 1, K).

The mode of vascular supply to the lateral pinnae are entirely the same in all nodules except the uppermost one, so that, the process described in detail for one pinna will suffice for all (Text-fig. 1, M, N, and O; or a series of diagrams Text-fig. 1, T, U, and V). At first, from the ventral bundle *VB*, there separates a bundle *fl*₁, and from a lateral bundle *l*, there segments *fm*, both of which (i. e. *fl*₁ and *fm*), meanwhile, become continuous (Text-fig. 1, T); then the portion including *fm* and *fl*₁ enters the base of the secondary petiole, and, at the same time, a bundle *fl*₂ again branches out from the ventral bundle *VB*, to fuse the bundle *fm* with its end which is just free from *VB* (Text-fig. 1, T-V). The strand for a pinna thus formed is of an arc in the transverse section, the main part of which is composed of a middle portion (*fm*) derived from the lateral bundle and both lateral portions (*fl*₁ and *fl*₂) derived from the ventral bundle. The branches (*r*₁ and *r*₂) of a ridge bundle occupy both ends of this arc. The same process is carried on at each nodule. The lateral bundle which is reduced by the vascular supply for the pinna, is reinforced at each nodule by a branch of the median bundle; and thus the size among the bundles remains nearly equal in the successive internodes, though each bundle diminishes gradually through the frequent vascular supply. In the higher internode, both lateral bundles tend to fuse with the median bundle so as to form a small continuous arc (Text-fig. 1, P). Just below the highest nodule, the vascular supply for the glandular process takes place from the ventral bundle exactly in the same manner as in the former case (Text-fig. 1, Q). The condition in the highest nodule is shown in a series of diagrams (Text-fig. 1, W-Y), the process being as follows:—a pair of bundles (*fl*₁ or *fl*₁' in Text-fig. 1, W) detach themselves from each end of the ventral bundle to fuse with each end of the dorsal arc (Text-fig. 1, R and X); meanwhile, the remains of the ventral bundle is invaginated so as to divide it into two parts *fl*₂ and *fl*₂', and the dorsal arc is also divided into two (*fm* and *fm*') leaving a small fascicle *tm* between them

(Text-fig. 1, R and X): then some fascicles tl and tl' are separated from fl_2 and fl'_2 , and are fused with tm to form the vascular supply for the terminal appendage (Text-fig. 1, Y); and the main bundles fl_1 , fm , fl_2 , and fl'_1 , fm' , fl'_2 , are fused into a pair of continuous arcs, in which fm and fm' occupy the middle portion (Text-fig. 1, Y and S); the ridge bundles rb and rb' are fused with both extremities of each arc. Thus, the constitutions of the strand for a pinna of this nodule is exactly the same as in the case of other pinnae (compare Text-fig. 1, W-Y with T-V). Though the vascular supply to the terminal appendage is composed only of a few small fascicles, there are some reasons to consider this appendage as abortive leaf-segments; some further remarks will be made subsequently.

Albizzia Lebbek BENTH. [Text-fig. 2, A-H]. Leaves even-bipinnate, pinnae 6-10 pairs, each with numerous leaflets, the vascular course being nearly the same as in the former species.



Text-fig. 2. *Albizzia Lebbek* (A-H, $\times 8$): A-D, pet. bas.; E, pet. mid.; F-H, a nod.

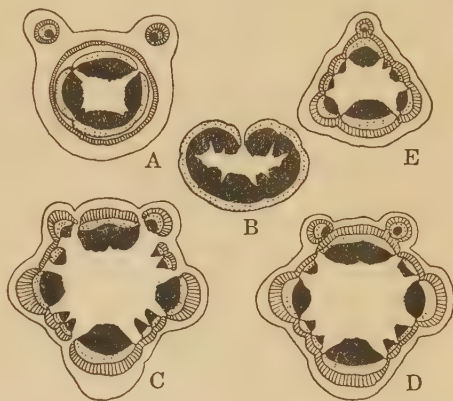
In this species, each of the two lateral foliar traces is in the form of a ringlet, divided temporarily into two lesser ringlets at the base of the pulvinus, while the one on the ventral side becomes continuous with the median foliar strand (Text-fig. 2, A and B); but the remaining ringlets are soon inserted so as to form a continuous ring at the middle of the pulvinus (Text-fig. 2, C and D), the constitution of which is exactly the same as that of *A. Julibrissin*.

Descriptions in the *A. Julibrissin*, of the disposition of the bundles in the slender part of the petiole, rachis, and in every nodule, are also applicable to this species (Text-fig. 2, E: the transverse section through the middle of the slender part of the petiole; and F-H: successive sections of a nodule). COL (1904; p. 114 and fig. XVIII. 4) mentioned that the cribral part of the arc in the base of the secondary petiole is folded inwards but no such cases were observed in the present study.

According to PETIT (1887; p. 69, and Pl. IV, fig. 24), a continuous vascular ring at the base of the petiole in *Albizzia lophantha* BENTH. (*Acacia lophantha*

WILLD. in his work), is divided into many distinct bundles, and the petiole is slightly flattened vertically at the "caractéristique". Moreover, complete phyllodes are found in this species, and in such leaves, bundles are more divided. COL (1904; p. 113 and fig. XVIII, 1 and 2) found the amphivasal concentric medullary bundles in the nodules of the main rachis in *Albizzia lophaniha* and *Albizzia Mollugo*. By the same author, it was mentioned that there occur some irregular dispositions of the bundles at the basal part of the petiole in the latter species.

Pithecolobium dulce BENTH. [Text-fig. 3, A; and Pl. VII, fig. 32]. The even-bipinnate leaf with a pair of pinnae consisting of a pair of leaflets. A tolerably large stipular bundle with the same origin as in *Albizzia Julibrissin* is supplied to each spiny stipule. Three foliar traces, each forming a ringlet, are directly connected into a continuous crescent. A pair of ridge bundles is separated, a large ventral bundle remaining between them. As the division of the dorsal arc occurs imperfectly, so the disposition of the bundles in the slender part of the petiole (Text-fig. 3, A; and Pl. VII, fig. 32) somewhat resembles that of the higher internodules of *A. Julibrissin*. Corresponding to the single ramification at the top of the petiole, all the petiolar bundles are divided into two groups, the abortive fascicules for the terminal appendage remaining between them. The constitution of these groups of bundles is the same as in the former example.



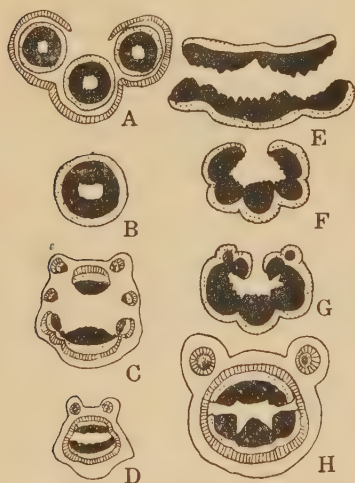
Text-fig. 3. *Pithecolobium dulce* (A, $\times 20$): pet. mid. *Pithecolobium saman* (B-E, $\times 8$): B, mid. of pulv., C, pet. mid., D, mid. of a lower internod.; E, mid. of a higher internod.

Pithecolobium saman BENTH. [Text-fig. 3, B-E]. Vigorous even-bipinnate leaves with 2-4 pairs of pinnae consisting of 2-5 pairs of leaflets. The crescent in the pulvinus has an interruption on its ventral side (Text-fig. 3, B). The disposition of bundles in the slender part of the petiole, however, coincides with former examples; that is, there are four bundles, a ventral and a median bundle, and two lateral ones. There are also a few small bundles insetted between the larger ones and a pair of ridge bundles which gradually migrate and take their regular position at the higher part of the petiole (Text-fig. 3,

C and D: show respectively the transverse section of the middle and the upper part of the petiole). No peculiarities are found in any nodule. At the uppermost internodule, the ridge bundles fuse together to form a single strand (Text-fig. 3, E) which separates again at the highest nodule. The vascular supply for each glandular process on the ventral side of each nodule shows the anastomose between each ridge bundle.

[2] ACACIEÆ.

Acacia villosa WILLD. [Text-fig. 4, A-D; Pl. VII, fig. 34]. An even-bipinnate leaf with 5-8 pairs of pinnae consisting of numerous leaflets. Three foliar traces, each representing a ringlet, fuse into a continuous ring at the



Text-fig. 4. *Acacia villosa* (A-D, $\times 12$): A, showing three foliar traces in the form of ringlets B, mid. of pulv.; C, pet. mid.; D, mid. of a higher internod. *Acacia arabica* (E-H, $\times 30$): E-G, pet. bas.; H, pet. mid.

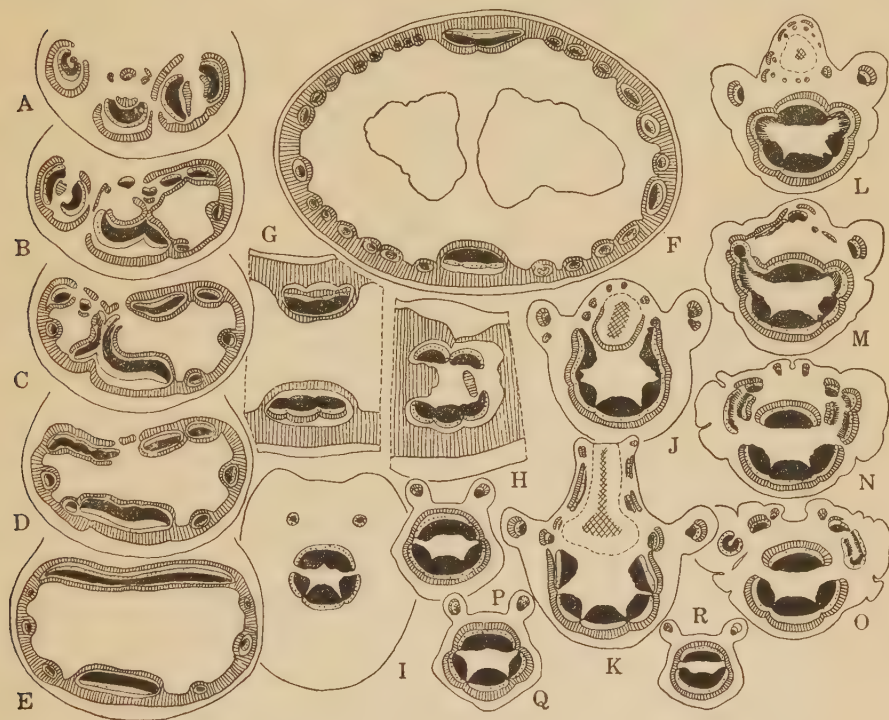
base of the pulvinus (Text-fig. 4, A and B). In the slender part of the petiole, there is a marked ventral bundle, a median bundle, two small bundles on each lateral side, and a pair of ridge bundles (Text-fig. 4, C; and Pl. VII, fig. 34). The mode of formation of such is the same as in former instances. At the nodule, the two lateral bundles fuse to the median bundle, and then the vascular supply for the lateral ramifications departs from the lateral bundles thus fused and the ventral bundle, in a manner similar to former examples. At the upper internodes, there is a ventral and a dorsal arc (Text-fig. 4, D).

Acacia arabica L. [Text-fig. 4, E-H].

Leaves even-pinnate, leaflets 10-20 paired. At the base of the petiole there are two large bundles which are situated on the ventral and dorsal part, the former of which is composed of both marginal portions of each foliar strand (Text-fig. 4, E). The ventral bundle is then divided into two, and the dorsal one is segmented into three; at the middle of the pulvinus, they form a deeply curved arc of five segments (Text-fig. 4, F). The ridge bundles are detached from the middle portion of both segments situated on both ends of this arc (Text-fig. 4, G), so that the departing portion of the ridge bundles differs from that of former examples. As the segments situated

on both extremities of the arc separate and again fuse into one at the transitional region between the pulvinus and the slender part of the petiole, therefore the topographical disposition of the bundle in the latter part (Text-fig. 4, H) shows a close resemblance to that of *Pithecolobium dulce* (cf. Text-fig. 3, A). No peculiarities are found in the nodules and internodes.

***Acacia sphærocephala* CHAM. et SCHLECHT.** [Text-fig. 5, A-R]. The even-bipinnate leaf with 5-9 pairs of pinnae consisting of numerous leaflets is characterized by the possession of vigorous spiny stipules. Though the bundles



Text-fig. 5. *Acacia sphærocephala* (A-H, $\times 10$; I-R, $\times 20$): A-I, pet. bas.; J, lower part of pet.; K, pet. mid.; L-O, a nod.; P-R, internods. on various height.

for each stipule are numerous, their departing portion exactly resembles the cases hitherto described. Both of the lateral margins of each foliar trace form a group of bundles situated on the ventral side, and the remains of each trace are fused to form a large dorsal bundle (Text-fig. 5, A-D). Then, the former group on the ventral side is fused into a large, laterally elongated bundle (Text-fig. 5, E). Meanwhile, stipular traces rise successively from the lateral margin of these two bundles (Text-fig. 5, E and F), the remaining bundles enter-

ing the swollen part of the petiole; thus one can easily recognize that the disposition of bundles in the basal part of the pulvinus (Text-fig. 5, G, H, and I) is similar to that of *Acacia arabica*. In the slender part of the petiole, as the bundles for the large nectary spreading along nearly the whole of the slender part are supplied successively from the middle portion of the ventral bundle, so the ventral bundle is widely separated into two, along nearly the whole length of the petiole (Text-fig. 5, J and K), reaching to just below the first nodule where they fuse again into one.¹⁾ The vascular supply for the lateral pinnae occurs in an ordinary manner (Text-fig. 5, L-O). Here we find some anastomose between the ridge bundles and the bundles for the nectary at the nodule. In many leaves, nectaries are found on the ventral side of a few lower nodules, but sometimes they are found on every nodule. In any case, each nectary is much smaller than that of the petiole; so that the topographical situation of the bundles in any internodule is not influenced by the nectaries (Text-fig. 5, P-R).

***Acacia confusa* MERR.** [Pl. VIII, figs. 47, 48, and 49]. In this species, the leaf is reduced to a simple phyllode, which is lanceolate, acuminate and is provided with many nerves and small stipules. At the base of the pulvinus, a deeply curved arc of five segments is formed (Pl. VIII, fig. 47), which soon becomes a continuous ring at the middle of the pulvinus, so that in these regions, no remarkable differences are found, as compared with cases of other species of *Acacia*. Then, the continuous ring thus formed, gradually becomes flattened in a vertical direction; and this ring is gradually divided into several segments—two bundles situated each on the ventral and dorsal sides, and four or five main pairs of bundles, in the basal part of the phyllode, the xylem of each pair facing each other (Pl. VIII, figs. 48 and 49). In the lamina-like flattened portion of the phyllode, numerous small bundles, branching from these main bundles, anastomose each other to form a network, which are, in transverse section, also arranged in two rows and the relative position of xylem and phloem retains that of the mother bundles.

ACQUA (1887; pp. 54-55) stated that the same condition as that mentioned above was observed in many species of *Acacia* (*A. linealis*, *A. melanoxyton*, etc.). PETERS (1912) treated many phyllodes of *Acacia*, systematic-anatomically, and showed some figures, but he did not attach any importance to the arrange-

1) Condition of the vascular supply to the nectary of *Acacia cornigera* WILLD. was well-illustrated by SCHWENDT (1906).

ment of the vascular bundles (cf. historical, p. 228). In confirmation of her "Phyllode Theory" on the monocotyledonous leaves, ARBER (1925; p. 100 sqq.) treated the phyllodes found among many species of *Acacia* (*A. uncinella*, *A. neurophylla*, etc.), well illustrating the transformation from the normal petiole to the phyllode.

[3] *EUMIMOSÆ.*

Mimosa pudica L. [Pl. V, fig. 4; Pl. VII, fig. 31; and Pl. VIII, fig. 37]. An even-bipinnate leaf with two pairs of ramifications in this species shows a close resemblance to the palmately compound leaf owing to the extreme shortness of the internode. Three ringlets of the foliar traces fuse into two bars situated dorsally and ventrally. The ventral bar is composed of both marginal portions of each foliar trace, and this is exactly similar to the case of *Acacia arabica* or *A. sphærocephala*. The vascular supply for the considerably broad stipules arises successively from both ends of these bars, and the remaining bars fuse into a continuous ellipse, which gradually decreases in area, to become almost a single mass, at the middle of the pulvinus (Pl. V, fig. 4): in other words, the convergence of the stele in this region occurs more vigorously than in that of the other species hitherto described. That this situation of bundles has an intimate connection with the remarkable sleeping movements of the leaf, was repeatedly reported by many authors (PREUSS, 1885; SCHWEDNER, 1897; HARBERLANDT, 1924; etc.). This converged stele again diverges at the transitional region between the pulvinus and the slender part of the petiole, and the ellipse, meantime, is divided into a large ventral bundle and an arc formed dorsal one. Soon after a ridge bundle separates from each end of the arc (Pl. VIII, fig. 37), the arc itself divides into three.¹⁾ No peculiarities are found in regard to the disposition of bundles in the slender part of the petiole (Pl. VIII, fig. 31), nodules, and the extremely short internode.

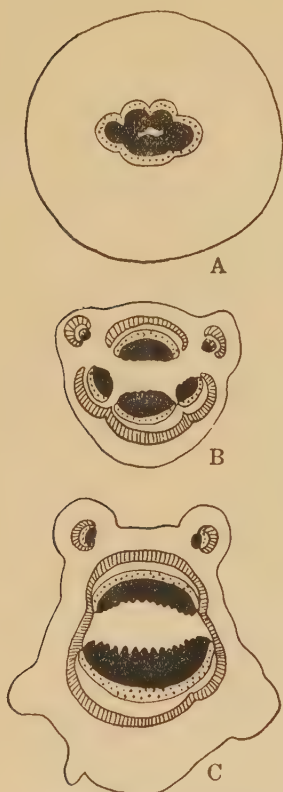
Mimosa Spegazzinii PIROTTA [Text-fig. 6, A and B]. Leaves even-bipinnate with a pair of pinnae consisting of numerous leaflets. A vigorous constriction of the stele at the pulvinus is also found (Text-fig. 6, A). In the slender part of the petiole, there is a large ventral bundle, three bundles

1) PETIT (1887; p. 68, and Pl. IV, fig. 25) described, ".....un cercle divisé en deux moitiés inégales et deux faisceaux latéro-supérieurs". This description seems to have its foundation in his observation on the transitional region, between the pulvinus and the slender part of the petiole, or the portion just below the nodule.

situated on an arc, and a pair of ridge bundles (Text-fig. 6, B). All of these bundles enter a pair of pinnae attaching at the top of the petiole, and only a few abortive bundles remain for the terminal appendage.

***Mimosa myriophylla* BONG.** [Text-fig. 6, C].

Even-bipinnate leaves, which in this species, are somewhat different from those of the former two examples; that is, the stipules are spiny, and the lowest pair of pinnae are attached just above the pulvinus, whilst the many other pairs of pinnae consisting of numerous leaflets are attached to the nodules which are separated by rather long internodes; so that no slender part of the petiole is found. Three foliar traces are fused into a continuous ring at the pulvinus. Though the ridge bundles are also branched from the ventral portions of this ring, which are considerably separated, the departing portions of the ridge bundles differ from the case of *Mimosa pudica* or *Mimosa Spegazzinii*, and rather show a resemblance to those of *Acacia arabica* or *A. sphaerocephala*. Corresponding to the morphological feature of the leaf, the vascular supply for the lowest pair of pinnae occurs at the portion just above the pulvinus, the mode of departure of this vascular supply, however, as well as of that for each pinnae attached one above other, exactly corresponding to that of the former numerous examples. In every internodule, there is a large ventral bundle, a large dorsal, and a pair of ridge bundles (Text-fig. 6, C).

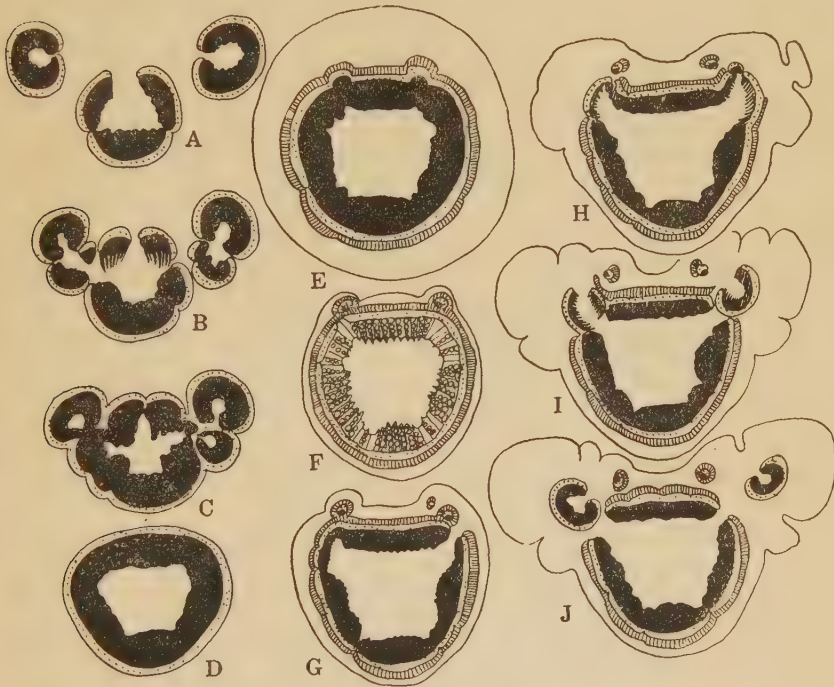


Text-fig. 6. *Mimosa Spegazzinii* (A and B, $\times 27$): A, mid. of pulv.; B, pet. mid. *Mimosa myriophylla* (C, $\times 25$): pet. mid.

[4] **ADENANTHEREÆ.**

***Adenanthera microsperma* TEIJSM. et BINN.** [Text-fig. 7, A-J]. Even-bipinnate leaves with 5-10 pairs of pinnae consisting of 8-15 leaflets. The disposition and fusion of three foliar strands at the base of the pulvinus, show a remarkable resemblance to those in *Albizzia Lebbek*; that is, each lateral foliar trace is divided into two (Text-fig. 7, A and B), the dorsal one becoming

continuous to the lateral part of the median foliar trace so as to form a deeply curved arc (Text-fig. 7, C); then the remaining half is soon inserted into the median foliar strand, and thus a continuous ring is formed at the middle of the pulvinus (Text-fig. 7, D). The only difference, in this region, between this species and *A. Lebbek*, lies in the fact that the dorsal half of each lateral foliar trace becomes continuous to the median one at first. At the transitional part between the pulvinus and the slender part of the petiole, the continuous ring



Text-fig. 7. *Adenanthera microsperma* (A-J, $\times 20$): A-E, pet. bas.; D, mid. of pulv.; F, pet. mid.; G-J, a nod.

mentioned above increases its diameter, and a pair of feeble ridge bundles is departed from two separated ventral portions of this ring (Text-fig. 7, E). This condition remains throughout the whole slender part of the petiole and in every internodule (Text-fig. 7, F). Just below each nodule, the continuity of this ring is broken at the two latero-ventral portions (Text-fig. 7, G), and the bundles for the pinnae are supplied from these portions in a manner similar to that of former examples (Text-fig. 7, H-J).

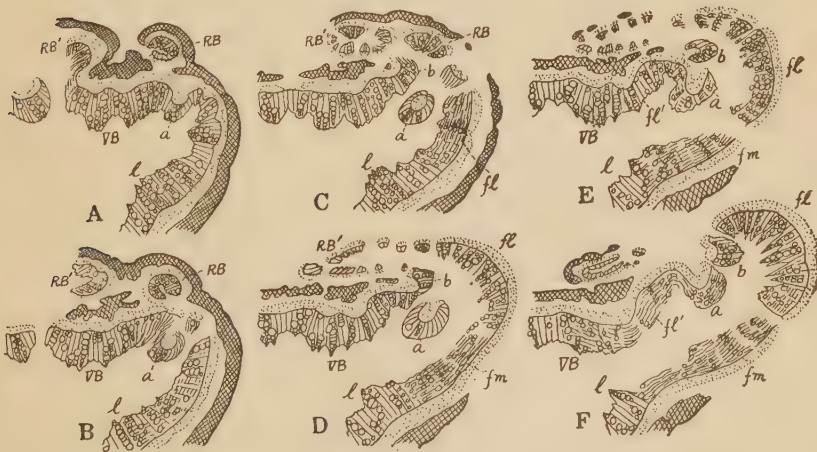
B. CAESALPINIOIDEÆ.

[1] DIMORPHANDREÆ.

Erythrophleum guineense G. DON [Text-fig. 8, A-M; and Text-fig. 9, A-F]. Leaves even-bipinnate, long-petiolate; pinnae 3-4 paired; 6-8 leaflets in each pinna. Seven or nine foliar traces, which issue from distinct gaps of the stem (Text-fig. 46, C), each in a form of a ringlet, are fused into a continuous crescent at the base of the pulvinus (Text-fig. 8, A and B). Similarly to the case of *Albizzia*, the ventral chord of this crescent is composed of the lateral margins of the foliar traces. A pair of feeble ridge bundles are detached from the portion a little way from either end of the chord, and, at the same time, the crescent gradually changes into a complete ring (Text-fig. 8, C). This ring remains throughout the whole length of the petiole. Often the ridge bundles temporarily reunite to the ring at the middle of the slender part of the petiole (Text-fig. 8, D). The departure of bundles for the pinna is somewhat complicated, as is shown in Text-fig. 8, E-G, which show a few transverse sections, in the successive height, of a nodule; Text-fig. 9, A-F show the details in that region. For the sake of convenience the ventral and lateral portions of the ring are respectively designated as *VB* and *l*, both of which are separated by the invagination of a bundle *a* (Text-fig. 9, A and B). A portion occupying the middle of the ventral side of this ring projects outwards, and soon it is divided into two (*RB'* in the figures); at a higher level, *RB'* ramifies into many and anastomoses with a ridge bundle *RB* (Text-fig. 9, D and E). On the other hand, a small segment of this ring invaginates to form a small amphivasal concentric bundle *a* (Text-fig. 9, A-C), the composite strands *fl* and *fm* springing off from the margin of *l* (Text-fig. 9, C-F). At the same time all parts of *RB* and a few branches of *RB'* fuse with the margin of *fl* and *VB* (Text-fig. 9, C and D), and a small segment *b* is separated from *VB* and is fused with *fl* at a higher level; *a*, which now becomes a collateral condition, again fuses to the margin of *VB* (Text-fig. 9, D and E), and then a segment *fl'* accompanying *a* separates from *VB* (Text-fig. 9, F). Thus, the vascular supply to a pinna is composed of these five segments—*a*, *b*, *fl*, *fl'*, and *fm*, all of which, at the base of the pinna, are fused into a closed ring having a slight invagination on its ventral portion (Text-fig. 8, G). The remains of *RB'* become a new ridge bundle of the internodule just above. At the higher nodule the same condition is repeated for the vascular supply to the pinnae, and at the



Text-fig. 8. *Erythrophleum guineense* (A-M, $\times 12$): A-C, pet. bas.; D, pet. mid.; E-G, a nod. (Compare Text-fig. 9); H, an internod.; I-M, highest nod.



Text-fig. 9. *Erythrophleum guineense* (A-F, $\times 25$): details of vascular supply to a pinna (Compare Text-fig. 8, E-G).

highest nodule, there remain a few abortive fascicles for the terminal appendage (Text-fig. 8, I-M).

[2] *AMHERSTIÆ*.

Saraca indica L. [Text-fig. 10, A-O]. Even-pinnate leaves with 2-3 pairs of leaflets; long-petiolate. Trilacunar foliar traces, each of which takes the form of an arc with incurved ends (Text-fig. 10, A), are fused into a continuous ring, including a small amphivasal concentric ringlet within it, in the middle of the pulvinus (Text-fig. 10, E). The ventral portion of this ring is composed of each lateral margin of three foliar traces as in the case of *Albizzia Julibrissin*; and the inner ringlet is derived from the invagination of both margins of the median foliar trace, as is shown in the series of figures



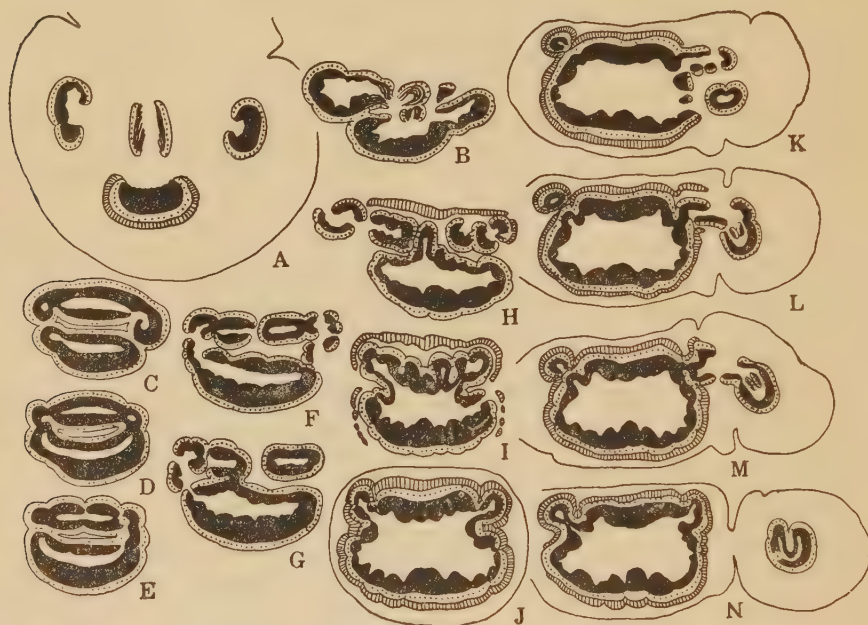
Text-fig. 10. *Saraca indica* (A-O, $\times 12$): A-I, pet. bas.; J, pet. mid.; K-O, a nod.

(Text-fig. 10, B-E). Then the ventral portion of the outer ring is interrupted, and the inner bundle which now becomes collateral is inserted into this interrupted portion to form a continuous ring having an invaginated portion on its ventral side (Text-fig. 10, F-H). At the transitional region, between the pulvinus and the slender part of the petiole, this ring is temporarily divided into a large ventral bundle and a large dorsal arc (Text-fig. 10, I). From both extremities of the latter, the ridge bundles are separated, and then the main bundles are again closed into a continuous ring with a slight invagination on its ventral side. The same condition remains throughout the whole length of the slender part of the petiole (Text-fig. 10, J). At the nodule, two or three

small amphivasal concentric bundles are invaginated from the ventral portion of this ring (Text-fig. 10, K and L). The vascular supply to the pinna occurs, as in the usual manner, from the lateral portion of this ring, and in this case a small portion of the invaginated bundles is joined to the pinna-bundles; a small part of the ridge bundle is also joined. Two small amphivasal concentric bundles (*a* and *b* in Text-fig. 10, M) are newly invaginated from the bundles for the leaflet, and in the petiolule of a leaflet, there is seen a continuous ring including a small medullary bundle which is furnished by the fusion of the small bundles *a* and *b* (Text-fig. 10, M-O). On the other hand, at a level just above the nodule, the rachis bundle again becomes a continuous ring enclosing a minute bundle (Text-fig. 10, O); but, a little higher, this minute bundle enters the ventral portion of the outer ring. The same complex arrangement of the bundles is repeated at each nodule.

***Amherstia nobilis* L.** [Text-fig. 11, A-N]. Leaves even-pinnate; leaflets, 4-7 paired; the lowest pair is attached to the nodule just above the pulvinus. Out of the trilacunar traces, the median one from the median gap is the largest (Text-fig. 11, A). These traces are fused into a large outer ring and a small inner one in the middle of the pulvinus, the process being the same as in the case of *Saraca indica* (Text-fig. 11, B); but these two rings are usually fused to each other with their lateral portions, and are often separated into two flattened rings situated on the ventral and dorsal side (Text-fig. 11, B and C). That process, in which the outer ring and the inner one form the dorsal and ventral rings, which is not constant in this species, is constantly observed in some species of *Bauhinia* and *Cercis* (cf. p. 253 sqq.). In any case, however, these two rings are found at the higher portion of the pulvinus, and the ventral ring is divided into the two smaller imperfect rings (Text-fig. 11, D). The vascular supply to the lowest pair of leaflets occurs from both lateral portions of the dorsal ring and a lateral portion of the ventral rings, and the mode of departure is the same as in many cases described above, though its constitution is somewhat simpler than the others (Text-fig. 11, F-H; cf. Text-fig. 11, K-N). Above the first nodule, the ventral small rings and the dorsal ring fuse, passing through a complicated process, into a continuous ring with a somewhat irregular outline (Text-fig. 11, G-J: J shows the transverse section through the middle portion of the first internodule). The separation of ridge bundles is incomplete, and they are present only as a pair of protrusions of the ring through the internodes, while just below a nodule they are separated from the ring. The vascular supply to each leaflet, above the second

nodule, occurs from two portions of the lateral sides of the ring (Text-fig. 11, K-N). The strands for a leaflet are composed of a deeply curved arc with a pair of small bundles in its concavity, the origin of such small bundles being clearly shown in these figures; at a little higher level, each of these small bundles is respectively fused to each end of the arc, thus forming a continuous ring having a marked invagination on the ventral side (Text-fig. 11, N). It may certainly be said that these invaginated portions of the ring correspond



Text-fig. 11. *Amherstia nobilis* (A-N, $\times 25$): A, showing three foliar traces; B and C, lower part of pulv.; D, mid. of pulv.; E-H, top of pulv., the bundles for the lowest pinna are departed; I, lower part of 1st internod.; J, mid. of 1st internod.; K-N, a nod.

to the bundles *a* and *b* in the case of *Saraca indica* (cf. Text-fig. 10, M-O). The bundles for a pair of leaflets attached to the top of the rachis have the same constitution, and a few abortive bundles are supplied for the terminal appendage.

Tamarindus indica L. [Pl. V, fig. 7 and 8]. Even-pinnate leaves consisting of numerous leaflets. Three foliar traces come out from three distinct gaps of the stem. They are fused into a large outer ring and a small inner amphivasal concentric ring (Pl. V, fig. 7). The xylem elements of the ventral portion

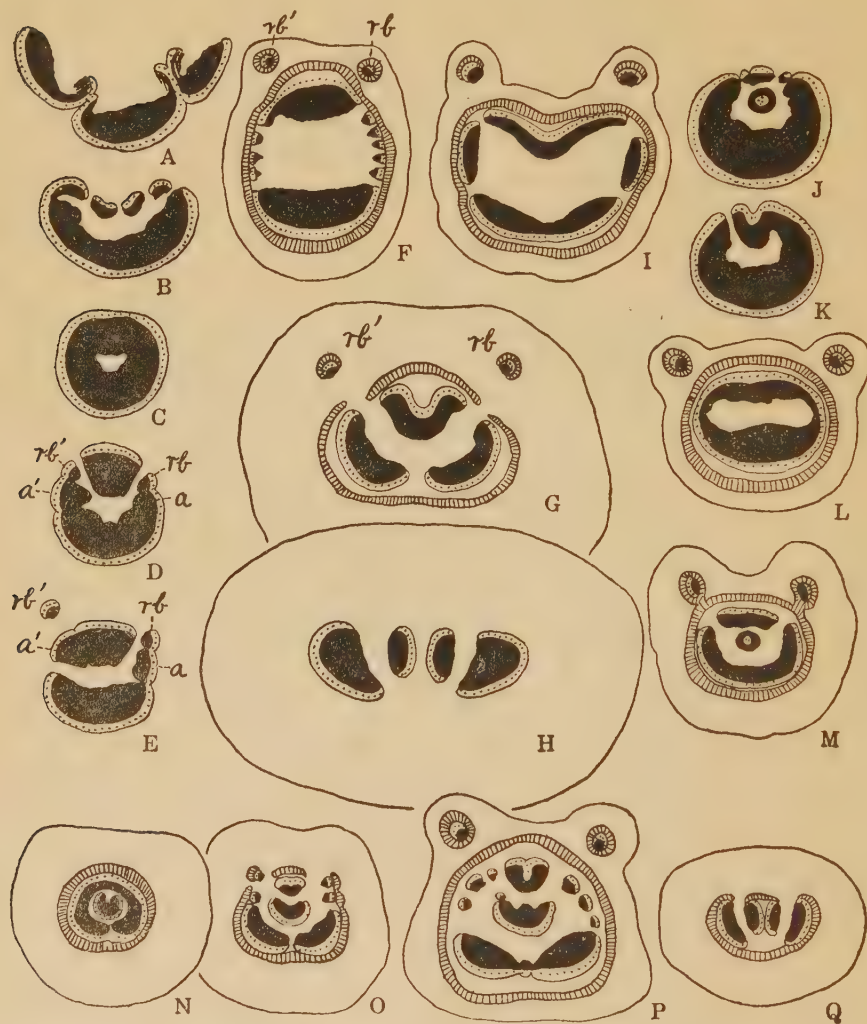
of the outer ring are slightly reduced. In the transitional region between the pulvinus and the slender part of the petiole, both the inner and outer rings open at the ventral side and then are fused—after a ridge bundle is separated from each end of the dorsal arc—into a ring with a slightly invaginated portion on its ventral side, as is found in *Saraca indica* (Pl. V, fig. 8).¹⁾ In this ring, we can distinguish a ventral, a median, and a pair of lateral bundles, in imperfect separation. The vascular supply to a leaflet is the same as in the case of many species of *Mimosoideæ*.

[3] *BAUHINIEÆ*.

Bauhinia alba BUCH.-HAM. [Text-fig. 12, A-H; Pl. V, fig. 6; Pl. VII, fig. 35; and Pl. VIII, figs. 42 and 43]. Bilobed leaves, with 7-13 palmate nerves. Three foliar traces are fused into a continuous arc at the base of the pulvinus and, at this point, a pair of small bundles are detached, in the concavity of the arc, from the fusing point of the three traces (Text-fig. 12, A and B; and Pl. V, fig. 6). All of these bundles are fused into a continuous crescent having a slight invagination on the ventral side, but this crescent is soon transformed into a continuous ring at a higher level (Text-fig. 12, C). In the transitional region between the pulvinus and the slender part of the petiole the ring is divided into a ventral bundle and a large arc, and then a pair of ridge bundles (*rb* and *rb'*) are separated from both ends of the arc (Text-fig. 12, D). Just above, a segment of each end of the arc (*a* and *a'*) is separated, to fuse to the ventral bundle (Text-fig. 12, E). Throughout the whole slender part of the petiole, we find a large ventral bundle, a large dorsal one, a few minute bundles on both lateral sides, separated from the dorsal one, and a pair of ridge bundles (Text-fig. 12, F; and Pl. VII, fig. 35). Near the top of the petiole, the ridge bundles and the lateral bundles are fused with the large dorsal bundle into a large open arc, which is, meanwhile divided into two (Pl. VIII, fig. 42). On the other hand, the ventral bundle is gradually invaginated (Text-fig. 12, G) and then is divided into two; so that, at the top of the petiole, a pair of larger bundles and a pair of smaller ones situated between them, are found

1) PETIT (1887; p. 67 and Pl. IV, fig. 22) described "Dans le *Tamarindus indica* et le *Copaifera Langsdorffii*, nous voyons au contraire l'anneau inférieur principal surmonté de deux petits faisceaux", and also ACQUA (1887; p. 54) did "In questa specie i fasci corticali rimangono generalmente estranei al processo d'innervazione delle foglioline e da ultimo si fondono con la cerchia".

(Text-fig. 12, H; and Pl. VIII, fig. 43). The further ramification of these bundles is very complicated, as is diagrammatically shown in Text-fig. 13, A (cf.



Text-fig. 12. *Bauhinia alba* (A-H, $\times 25$): A-E, pet. bas.; F, pet. mid.; G and H, pet. top. *Bauhinia acuminata* (I, $\times 12$): pet. mid. *Bauhinia candicans* (J-L, $\times 25$): J and K, pet. bas.; L, pet. mid. *Bauhinia Galpinii* (M, $\times 12$): pet. mid. *Bauhinia purpurea* (N-Q): N and O ($\times 12$), pet. bas.; P ($\times 25$), pet. mid.; Q ($\times 12$), pet. top.

Text-fig. 13, B-D, *Bauhinia purpurea*). The larger bundles ramify into the definite number of the palmate nerves, each with an arc form in the transverse section, and both the smaller bundles are also divided into a definite number

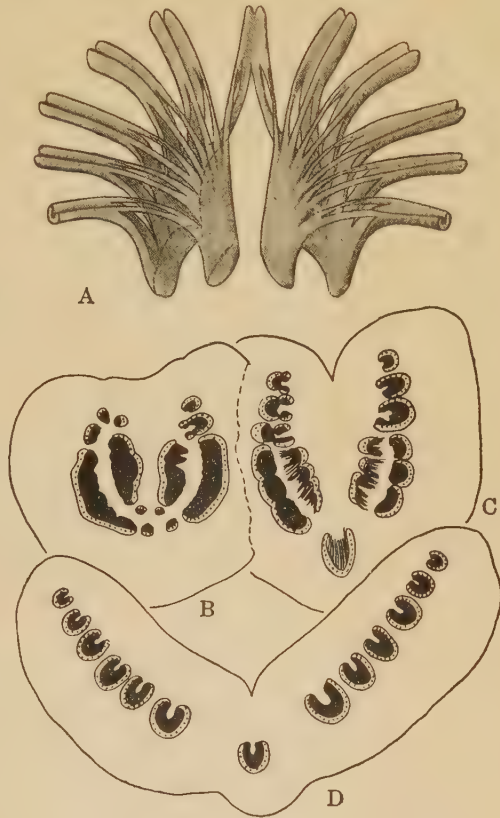
corresponding to that of the larger bundles; each branch is again divided into two, the lateral margins of each nerve being composed of these branches. The midrib of the lamina which is somewhat reduced, is furnished from both the larger and smaller bundles. In regard to a nerve, therefore, one can easily recognize that its constitution corresponds to the vascular supply for a leaflet in the case of many species of *Mimosoideæ*, e. g. *Albizzia Julibrissin*.

According to the descriptions of ACQUA (1887; p. 53), *Bauhinia racemosa* VAHL. and *Bauhinia aculeata* LIN. seem to show the same vascular course as in the case of *B. alba*.

***Bauhinia acuminata* L.** [Text-fig. 12, I]. Bilobed leaves with 7-9 palmate nerves. The invagination of the ventral bundle which is found only at the base and the top of the petiole in the former example, is seen throughout the whole length of the slender part of the petiole, and the petiolar bundles consist of a pair of ridge bundles, a large ventral, a pair of lateral bundles, and a large median one, the median part of the latter showing a slight reduction of the woody elements (Text-fig. 12, I:

the transverse section of the middle of the petiole). The other conditions are exactly the same as in the case of *Bauhinia alba*.

***Bauhinia candicans* BENTH.** [Text-fig. 12, J-L]. Bilobed leaves with 7-9 palmate nerves. The vascular course is somewhat different from others at the basal region; that is, three foliar traces are fused, at first, into a continuous arc having a pair of medullary bundles within its concavity, and then, the



Text-fig. 13. A, a diagrammatical reconstruction of the vascular system in the lamina-base in *Bauhinia*. *Bauhinia purpurea* (B-D, $\times 20$): the successive transverse sections of lamina-base showing the formation of palmate nerves.

arc becomes a continuous ring including an amphivasal concentric bundle derived from the medullary bundles (Text-fig. 12, J). In the transitional region between the pulvinus and the slender part of the petiole, the inner and outer rings open in arc, and then both are fused into a continuous ring (Text-fig. 12, K). This condition is nearly the same as in the former species and the further course is exactly similar to the case of *B. alba*. Moreover, owing to the presence of the inner concentric bundle at the pulvinus, an intimate resemblance to *Tamarindus indica* is found (Text-fig. 12, L: showing the transverse section of the middle of the petiole). In the slender part of the petiole, there is found no invagination of the ventral bundle.

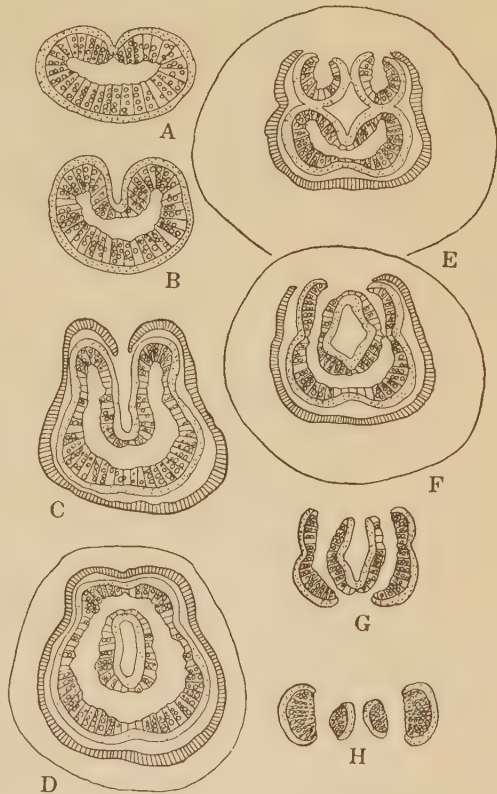
Bauhinia Galpini N. E. BR. [Text-fig. 12, M]. Bilobed leaves with 7-9 palmate nerves. As in the case of the former example, there is a small amphivasal concentric medullary bundle surrounded by a continuous outer ring at the pulvinus; and the latter is divided into a ventral bundle and a large arc, a pair of ridge bundles branching from both ends of the arc at the transitional region. The medullary bundle runs through the whole slender part of the petiole (Text-fig. 12, M) and, at the petiolar top, there form a pair of smaller and larger bundles, arranged side by side (cf. Text-fig. 12, H or Q); the smaller two, situated between the larger ones, are derived from the ventral and the medullary bundles, while the dorsal arc forms the pair of larger ones. According to BOUYGUES (1902; p. 140), the same condition is presented in *Bauhinia glandiflora*.

Bauhinia purpurea L. [Text-fig. 12, N-Q; Text-fig. 13, B-D; and Pl. V, fig. 9]. Bilobed leaves, 9-15 palmately nerved. The vascular system is slightly more complicated than in the other species. A continuous outer ring, which encloses a small collateral medullary bundle, is formed at the base of the pulvinus, its woody part being on the ventral side (Text-fig. 12, N). The outer ring is divided into a ventral bundle and a dorsal arc consisting of a pair of large segments which are often separated into two and a few small ones, at the transitional region between the pulvinus and the slender part of the petiole (Text-fig. 12, O). Through the slight change in the arrangement of bundles, in the middle part of the petiole, there are a pair of large bundles on the dorsal side, a pair of ridge bundles, a ventral—slightly invaginated—bundle, a medullary bundle, and a few minute lateral ones detached from the end of the bundles on the dorsal side (Text-fig. 12, P; and Pl. V, fig. 9). At the top of the petiole, they fuse into four bundles situated side by side (Text-fig. 12, Q), the inner two of which are derived from the ventral and medullary bundles.

ACQUA (1887; p. 53) examined this species and *Bauhinia glandulosa* DEC. and found a similar vascular course in both species.

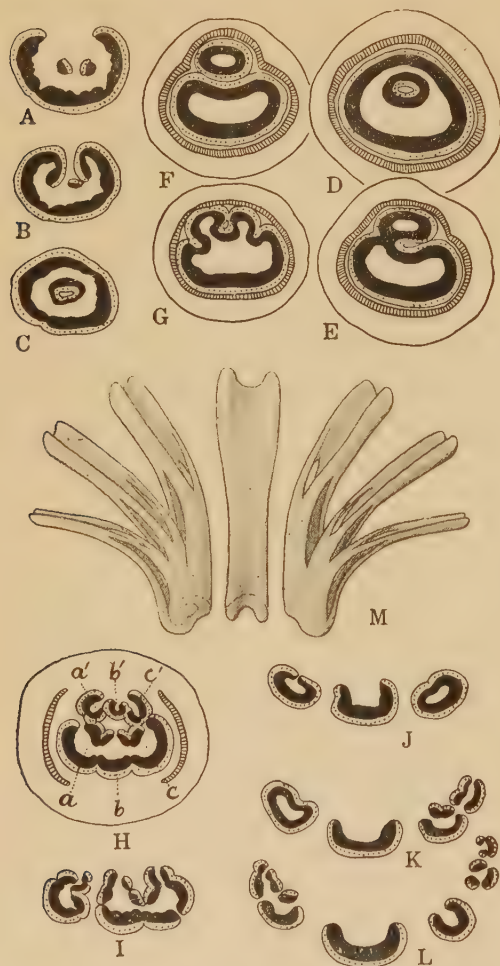
***Bauhinia japonica* MAXIM.** [Text-fig. 14, A-H; and Pl. V, fig. 10]. Bilobed leaves with 7-11 nerves. The vascular course in the petiole shows a condition somewhat more complicated than, and different from, the other *Bauhinia* species mentioned above. At the base of the pulvinus of the petiole, three foliar traces are fused into an ellipse (Text-fig. 14, A), the ventral portion of which is composed of each marginal part of these foliar traces. The ventral portion of this ellipse is gradually invaginated within the pulvinus (Text-fig. 14, B and C), and then the invaginated portion becomes an independent amphivasal ringlet and then remains in an outer ring (Text-fig. 14, D; and Pl. V, fig. 10: the transverse section through the middle of the petiole). The same condition is retained through nearly the whole length of the petiole, until just below the top of the petiole, where a flattened ellipse is formed from the dorsal parts of the inner and outer rings, and a pair of imperfect ventral ringlets from the dorsal parts of the rings (Text-fig. 14, E); sometimes, the imperfect ringlets are fused to form a continuous ellipse. These ringlets and the dorsal ellipse are rearranged and, at the top of the petiole, there form four bundles which are arranged side by side as in the cases of other species of *Bauhinia* (Text-fig. 14, F-H).

The same condition of the vascular course seems, according to PETIT (1887; pp. 66-67 and Pl. IV, figs. 71-79), to show the close resemblance of this species to those of *Bauhinia racemosa* and also to that of the other genera of *Bauhinia*, namely *Bandeiræa*.



Text-fig. 14. *Bauhinia japonica* (A-H, $\times 40$): A-C, pet. bas.; D, pet. mid.; E-H, pet. top.

Cercis chinensis BUNGE [Text-fig. 15, A-M; and Pl. V, figs. 12 and 13]. Simple leaves with 5-7 palmate nerves. As in the case of *Bauhinia alba*, three foliar traces are fused into a continuous arc with deeply incurved ends, and a pair of small bundles situated in the concavity of the arc at the base of the pulvinus



Text-fig. 15. *Cercis chinensis* (A-M, $\times 15$): A-C, pet. bas.; D-G, pet. mid.; H-J, pet. top; K and L, lamina-bas.; M, a diagram showing the ramification at the lamina-bas.

(Text-fig. 15, A). In the transitional region, between the pulvinus and the slender part of the petiole, the small bundles and the segments of both ends of the arc, are fused into an amphivasal concentric medullary bundle, and the remains of the arc is fused into a continuous ring enclosing the former within it (Text-fig. 15, B and C). It is seldom that this condition is retained throughout the slender part of the petiole; in many cases, the ventral portion of the outer ring and that of the medullary ringlet are fused into a small ring situated on the ventral side, and at a certain portion of the petiole, the remaining parts of both rings are also fused into a large ellipse on the dorsal side. Such a change of arrangement occurs irregularly, and between these two types, transitional conditions are found, so that, the transverse section through the middle of the

petiole represents, either a medullary ringlet surrounded by a large ring (Text-fig. 15, D; and Pl. V, fig. 13), or a ringlet on the ventral side separated from a large ring on the dorsal (Text-fig. 15, F), or transitional forms (Text-fig. 15, E;

and Pl. V, fig. 12). The fact that the ventral ringlet is, very occasionally, divided into two, which are respectively fused with the dorsal one (Text-fig. 15, G), seems to show the intimate relationship between the vascular system in the slender part of the petiole in this species and that of *Bauhinia japonica*. Just below the top of the petiole in the first form, these two rings are divided respectively into three segments (*a, b, c*, and *a', b', c'*, in Text-fig. 15, H). Then the segments *a* and *a'*, *b* and *b'*, and *c* and *c'*, are fused respectively to form a median bundle in the shape of U and the two lateral bundles in the form of more or less a complete ring (Text-fig. 15, I and J). In other cases these three bundles are composed of corresponding parts. The ramification of these bundles at the base of the lamina is shown in the diagrammatical reconstruction (Text-fig. 15, M): the median bundle furnishes the midrib, and the lateral ringlets supply the other palmate nerves in the same way in which the ventral and dorsal portions of each ringlet act respectively as large and small bundles at the top of the petiole in the case of *Bauhinia* species (cf. Text-fig. 13, A).

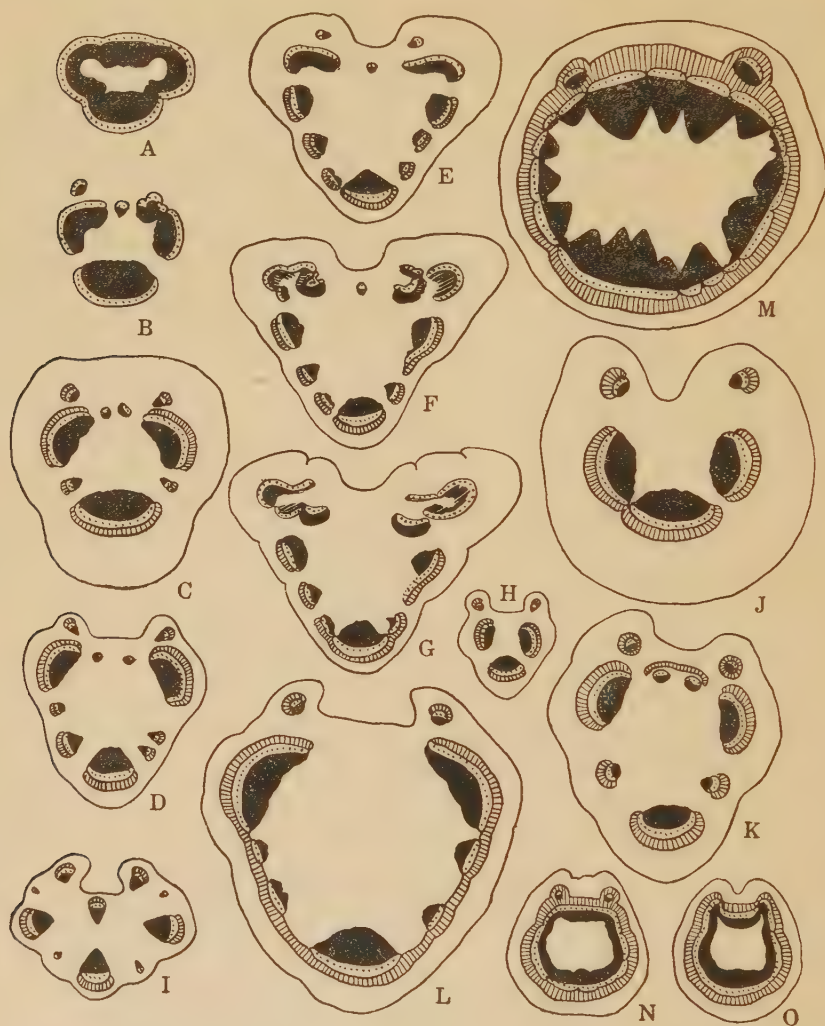
Also in *Cercis canadensis* L., a close similarity is found to the former species. In most cases a ventral ringlet and dorsal large ring are found, in the slender part of the petiole (Pl. V, fig. 11); other types are found only exceptionally. A series of photographs (Pl. VIII, figs. 40 and 41) well shows the formation of three bundles at the top of the petiole.

The vascular course in the petiole of *Cercis siliquastrum* L. was treated by PETIT (1887; pp. 65-66 and Pl. IV, figs. 31-36), BOUYGUES (1902; pp. 97-99), and ARBER showed a few figures (1925; p. 74. fig. 1ii, 17 A and 17 B). According to PETIT, the ventral ringlet and the dorsal large ring—as in the case of the present two species of *Cercis*—are also found throughout the slender part, and the ventral ringlet seems only to concern itself with the formation of the two lateral rings at the top of the petiole. But the case of the ventral ringlet being sometimes early divided into two at a certain lower level of the petiole is mentioned in the description of BOUYGUES. Also this condition is illustrated in ARBER's work, but the level of the section is not clearly shown.

[4] *CASSIÆ*.

Cassia torosa L. [Text-fig. 16, A-H]. Leaves, even-pinnate with 4-6 pairs of leaflets. At the base of the pulvinus of the petiole, three foliar traces are fused into a continuous ring in the same manner as in the case of *Albizia*

Julibrissin (Text-fig. 16, A). A pair of ridge bundles are detached from the ventral portion of this ring (Text-fig. 16, B), and at the same time the continuous ring is divided into three large bundles and a few minute bundles (Text-



Text-fig. 16. *Cassia torosa* (A-H, $\times 25$): A-C, pet. bas.; D, pet. mid.; E-G, a nod.; H, mid. of an internod. *Cassia Tora* (I, $\times 25$): pet. mid. *Cassia mimosoides* var. *nomame* (J, $\times 25$): pet. mid. *Cassia sulphurea* (K, $\times 30$): pet. mid. *Cassia marylandica* (L, $\times 30$): pet. mid. *Cassia Fistula* (M, $\times 25$): pet. mid. *Ceratonia Siliqua* (N and O, $\times 12$): N, pet. mid.; O, higher part of pet.

fig. 16, B and C). In the transverse section through the middle of the petiole (Text-fig. 16, D), unlike the cases of many species of *Mimosoidae* and some

of *Casalpinioideæ*, there are only very minute bundles on the ventral side (such a disposition of the bundles is quite general in many species of *Papilionatæ* as I shall subsequently state), so that one can easily recognize that a lateral bundle in this species corresponds, in the case of *Albizzia Jilibrissin*, to the lateral bundle itself together with a half of the ventral bundle. This idea is again confirmed by the fact that the vascular supply for a leaflet at a nodule, is branched in the same manner as in the case of *Albizzia Jilibrissin* after the lateral bundle has been temporarily divided into two (Text-fig. 16, E-G). The lateral bundle, which is decreased in size, is reinforced by the bundles situated between the lateral and the median bundles at the lower nodule, while, at the higher part, it is directly reinforced by the branches of the median bundle.

The same conditions are found in some other species of *Cassia*—namely *C. Tora* L. (Text-fig. 16, I), *C. mimosoides* L. var. *nomame* MAKINO (Text-fig. 16, J), *C. sulphurea* DC. (Text-fig. 16, K), *C. marylandica* L. (Text-fig. 16, L) (all these species have the even-pinnate leaves), though, as are shown in these figures, each species represents a peculiar topographical disposition of the bundles. *Cassia* sp. treated by PETIT (1887; p. 67, and Pl. IV, fig. 20) seems also to belong to this category.

Cassia Fistula L. [Text-fig. 16, M]. Even-pinnate leaves with 4-8 pairs of leaflets. The vascular course in the vigorous petiole differs from the above mentioned examples, and resembles rather that of *Adenanthera microsperma*; that is, three foliar traces, each representing a ringlet in the transverse section, are fused into a continuous ring at the pulvinus and at the transitional region, to the slender part of the petiole, a pair of ridge bundles which are separated from the ventral portion of this ring leaving its large segment between them. Then the ring is dissected into many bundles throughout the slender part of the petiole (Text-fig. 16, M: the transverse section in the middle of the petiole). The vascular supply to a leaflet takes place from the lateral portion of this ring in the usual manner.

Ceratonia Siliqua L. [Text-fig. 16, N and O]. Even-pinnate leaves with 2-3 pairs of leaflets. The continuous ring in the pulvinus is formed by the fusion of three foliar traces as in many former examples, and then a pair of ridge bundles are detached from two, widely separated, portions of this ring, such a condition being retained throughout the lower and middle portion of the slender part of the petiole (Text-fig. 16, N). On the higher level of the petiole, however, these ridge bundles are again attached to the ring, so that

a large, deeply curved arc and a large bundle situated on its chord are formed (Text-fig. 16, O). PETIT's description (1887; p. 67, and Pl. IV, fig. 21)—“l'anneau reste continu et forme à sa partie supérieure deux boucles, qui ne se détachent pas”—seems to be derived from his observation on the “caractéristique” of the petiole, but in every internodule of the rachis, the ridge bundles are again situated apart from the ring.

[5] *EUCÆSALPINIÆ.*

Cæsalpinia japonica SIEB. et ZUCC. [Text-fig. 17, A-R]. Leaves bipinnate; pinnae 6–10 paired and 8–12 pairs of leaflets in each pinna. A few stipular traces are furnished successively from each lateral foliar strand of trilacunar traces (Text-fig. 17, A and B; *St* and *St'* in Text-fig. 17, B), and at the base of the petiole, the median trace is divided into a few bundles which are arranged on a circle; at the same time, each lateral strand is also divided into two (Text-fig. 17, B and C; in Text-fig. 17, A–E, the bundles which belong to the original median strand are indicated in solid black, and those belonging to the lateral strands are roughly lined). A half of each lateral strand is then inserted into each lateral-dorsal side of the circle of the median strand (Text-fig. 17, D), while the ventral portion of the circle is divided into many minute bundles. Just at the level where the petiole becomes distinct from the stem, the other half of each lateral strand is inserted into the lateral-ventral side of the circle, thus forming a continuous ring which represents a somewhat triangular outline; in this the bundles originated from the median strand and those from the lateral ones are arranged alternately (Text-fig. 17, E). In this species, convergence of the stele, which was generally found in former examples, is never seen in the petiolar base. The vascular ring of triangular form becomes a flattened, obovate ring at the lower level of the petiole (Text-fig. 17, F), and then changes to an ovate form at the middle (Text-fig. 17, G). Such a form is retained in the internodule (Text-fig. 17, H and M). In this way, in the slender part of the petiole and internodes, many bundles, closely situated on a ring, are divided into five groups which are indicated by *m*, *l*₁, *l*₁', *l*₂, *l*₂' in Text-fig. 17, H (the group *m*, *l*₁, *l*₁', corresponds respectively to *m*, *l*, *l*' in the case of *Albizzia Julibrissin*, and *l*₂ and *l*₂' to *VB*). At the nodule, the vascular supply to the lateral pinnae occurs in the following manner. At first, the portion (*fl*, *fm*) including the elements of both lateral groups (*l*₁ and *l*₂, or *l*₁' and *l*₂') is detached from the circular arrangement to enter the base

of the petiolule of the pinna (Text-fig. 17, J); and, soon after, a bundle (fl') is again branched from l_2 (or l'_2) to enter the base of the petiolule (Text-fig. 17, J); soon, there forms a small arc on each end of which fl and fl' are



Text-fig. 17. *Cæsalpinia japonica* (A-R, $\times 12$): A-F, pet. bas. (in A-E, the median trace shows in solid black, lateral ones and the vascular cylinder of stem roughly lined); G, lower part of pet.; H, pet. mid.; I-L, a lower nod.; M, mid. of the highest internod.; N-R, the highest nod.

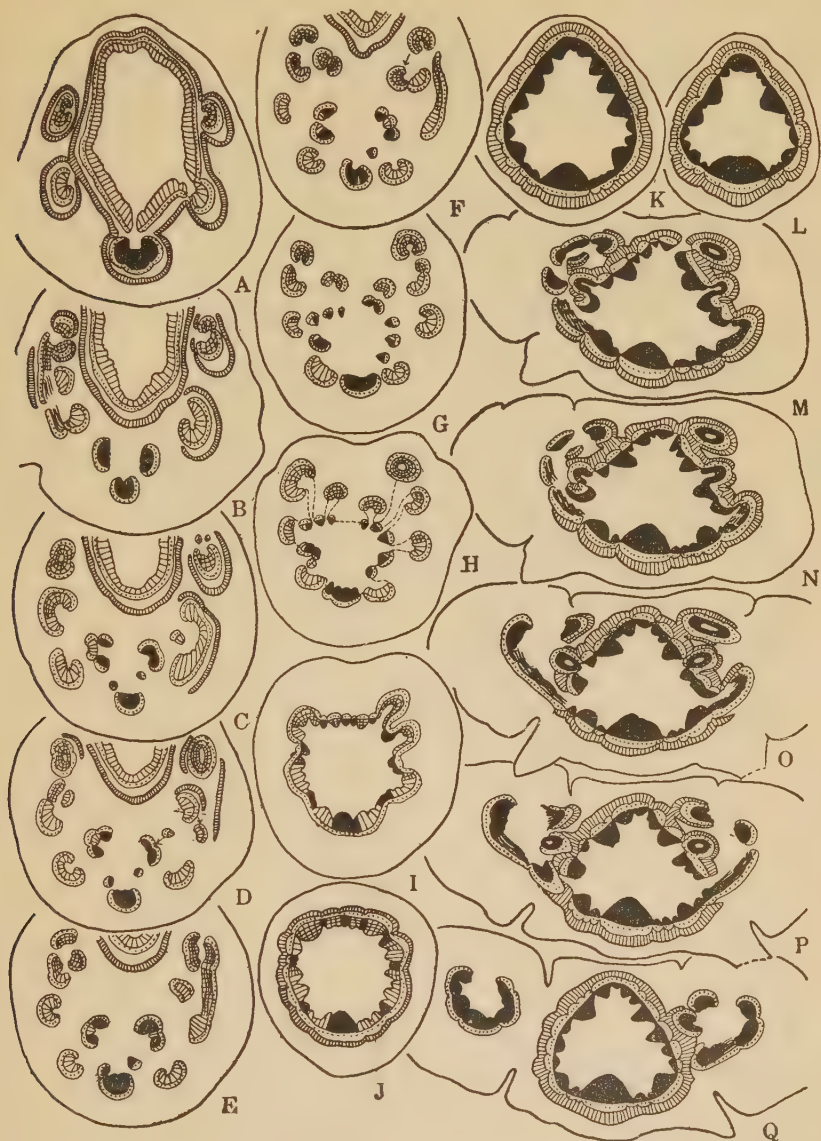
situated (Text-fig. 17, K). Meanwhile, a small amphicribal concentric bundle leaves the ventral portion just a little below the nodule, and soon divides into

two, one of which enters the base of the petiolule; this again divides into two, each half being fused respectively with each end of the arc for the pinna (Text-fig. 17, I-L). From this behaviour of those bundles that spring from the ventral portion of the circle, it seems to be most probable that this bundle corresponds to the ridge bundle of *Albizzia Julibrissin*, *Acacia villosa*, *Cassia Fistula*, etc., though in these species only a feeble fascicle is added to each end of the arc for the lateral pinna. Moreover, this suggestion becomes even more probable when one recalls the case of *Erythrophleum guineense*; in this, a bundle departs from the ventral portion of the circle at each nodule which, though it is not joined directly to the vascular supply for the lateral pinna at that nodule, yet is added to that for the pinna attached to the nodule on the next height (cf. Text-fig. 9, A-F). There seems to be no doubt that this bundle is also a kind of ridge bundle in its nature, although such a name seems somewhat unsuitable in this case. At the top of the rachis, as well as in the other nodules, there is a bundle on the ventral side in the same manner, and the circle itself is divided into two, leaving a few abortive bundles for the terminal appendage, as in other cases; so that, the constitution of the strands for the pinnae is the same as that for the other pinnae (Text-fig. 17, N-R).

Cæsalpinia Sappan L. [Text-fig. 18, A-Q]. Bipinnate leaves with 10-12 pairs of pinnae; leaflets, 10-15 paired in each pinna. Five foliar traces arise from their own gaps in the stem (Text-fig. 18, A; in Text-fig. 18, A-J, the median trace and the bundles originated from this trace are indicated in solid black, the outermost lateral traces crossed, and the other lateral traces roughly lined). The outermost lateral traces furnish the traces for the large stipules which abscise early. The five traces are fused into a continuous ring, by the same complicated process as in the case of *C. japonica* (Text-fig. 18, A-J).¹⁾ The bundles derived from the outermost lateral traces are chiefly situated on the ventral half of this ring, and those from the other lateral strands, on the dorsal half, while those from the median strand are inset into various portions of the ring; thus, the topographical condition in the petiole and internodes is the same as the former example (Text-fig. 18, K and L). At each nodule, however, a difference is found in that, though the bundle corresponding to *fl* and *fm* in the case of *C. japonica* is detached from a definite portion, the bundle corresponding to *fl'* is detached from the other

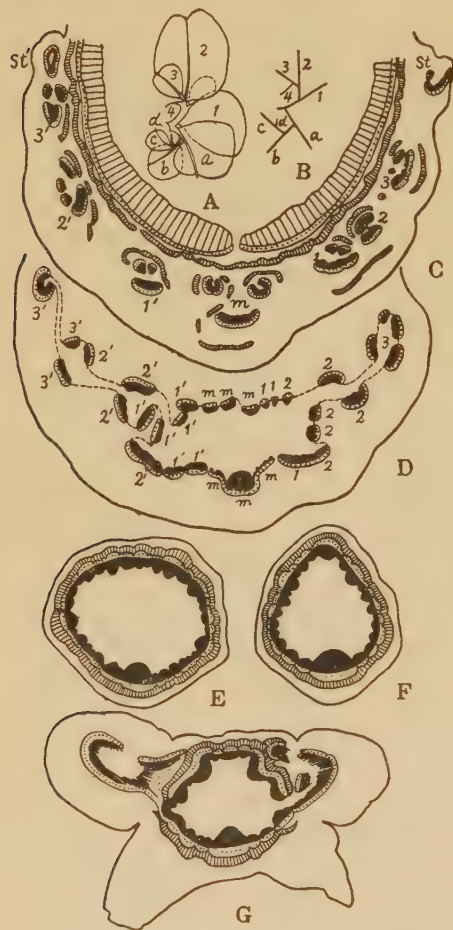
1) The vascular system in the region represented by Text-fig. 18, A-I is diagrammatically reconstructed in Text-fig. 48, G.

portion as is shown in Text-fig. 18, M-Q (in fig. Q, the constitution of the strand for the lateral pinna is well seen).



Text-fig. 18. *Cæsalpinia Sappan* (A-J, $\times 8$; K-Q, $\times 16$): A-J, node of stem and pet. bas. (the median trace and bundles from this trace are indicated in solid black, the outermost traces crossed, and the other ones roughly lined); K, pet. mid.; L, mid. of a lower internod.; M-Q, a lower nod.

Cæsalpinia Bonducella FLEM. [Text-fig. 19, A-G; and Pl. V, fig. 1]. Bipinnate leaves with 6-12 pairs of pinnae, leaflets 6-14 in each pinna. At the node of



Text-fig. 19. *Cæsalpinia Bonducella* (A and B, $\times 1\frac{1}{2}$; C-G, $\times 8$): A, a stipule; B, a diagram showing ramification of the stipule; C and D, pet. bas. (m, 1, 2, 3, 1', 2', and 3', show the bundles originated from these different traces); E, pet. mid.; F, mid. of a lower internod.; G, a nod.

the stem there are seen seven gaps (Pl. V, fig. 1), from each of which a foliar trace issues. The traces for the stipule¹⁾ are furnished from the outermost lateral strands. The conditions in the petiolar base show nearly the same complication as in the case of the former two examples (Text-fig. 19, C and D); but, in this species, the alternate disposition in the vascular ring is comparatively rare, and from the view-point of the destination of the foliar traces, the constitution of the ring shows a rather intimate resemblance to the case of *Erythrophleum guineense*. The elliptical outline of the middle of the slender part of the petiole (Text-fig. 19, E), transforms itself to an ovate outline in the internodes (Text-fig. 19, F). The vascular supply to the lateral pinnae occurs exactly in the same manner as in the case of *C. japonica* (Text-fig. 19, G).

According to PETIT (1887; p. 67, and Pl. IV, fig. 19), *Cæsalpinia echinata* represents the trilacunar type, and in the petiole, there is seen a complete ring (in his figure, this ring is represented as a continuous ring).

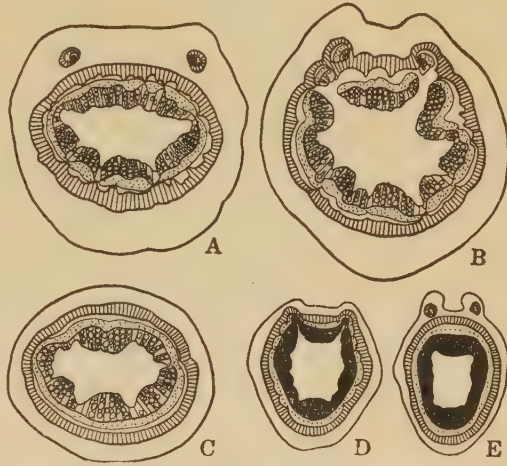
1) As is represented in Text-fig. 19, A, the stipule shows the complicated form, the ramification of which is shown diagrammatically in fig. B.

Gleditschia japonica SIEB. et ZUCC. [Text-fig. 20, A and B]. Leaves even-pinnate with 6-15 pairs of leaflets or even-bipinnate leaves with 4-8 pairs of pinnae, each of which has 8-14 of leaflets.¹⁾ This species shows a close resemblance to *Cassia Fistula* in the vascular course of the petiole. In many cases, a slightly flattened continuous ring and a pair of small ridge bundles are found in the transverse section of the slender part of the petiole (Text-fig. 20, A). But, sometimes, the ring is somewhat irregular and the separation of the ridge bundles are seldom complete (Text-fig. 20, B).²⁾ There are no peculiarities in any nodule.

Hæmatoxylon campechianum L. [Text-fig. 20, C]. Even-pinnate leaves with 3-4 pairs of leaflets. The arrangement of the petiolar bundles shows a close resemblance to the ordinary cases of former species, except as to the absence of the ridge bundles (Text-fig. 20, C). But I must not omit to state that very

occasionally I found cases showing a slight tendency to the formation of ridge bundles.

Poinciana regia Boj. [Text-fig. 20, D and E]. Leaves even-bipinnate with 10-20 pairs of pinnae, leaflets numerous. There is also a continuous ring through the petiole and rachis, in which the separation of the ridge bundles, contrary to the case of *Ceratonia Siliqua*, is incomplete in the lower and



Text-fig. 20. *Gleditschia japonica* (A and B, $\times 20$): pet. mid. *Hæmatoxylon campechianum* (C, $\times 40$): pet. mid. *Poinciana regia* (D and E, $\times 17$): D, pet. mid.; E, higher part of pet.

1) The leaves attaching to the short-shoot are always even-pinnate, and those, to the long shoot, are even-pinnate, and even-bipinnate, or a transitional form between the two.

2) As a general rule—though there is no regularity in this distinction—the laterally flattened vascular ring is apt to occur in those leaves attached to the short-shoot, while the vertically elongated ring, in those attached to the long-shoot. According to BURGER's work on *Populus tremula* L. (1920; pp. 61-67), slight distinctions in the topographical conditions in the transverse section of the petioles are found among those of "Kurzttrieb", "Langtrieb", and "Johannistrieb",

middle portion of the petiole, (Text-fig. 20, D), though they are completely separated at the higher part of the petiole (Text-fig. 20, E).

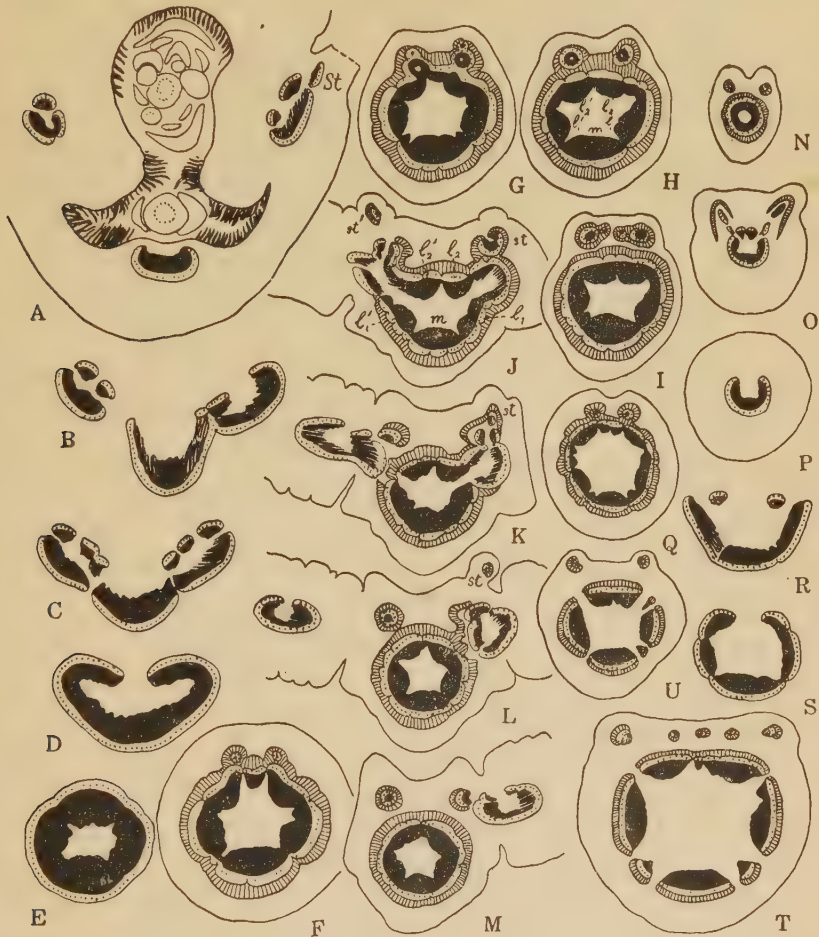
C. PAPILIONATÆ.

[1] *SOPHOREÆ*.

Styphnolobium japonicum SCHOTT (*Sophora japonica* L.) [Text-fig. 21, A-P]. Leaves, odd-pinnate, with rather large stipules which abscise early; leaflets, 6-8 paired. A very minute stipel is found at the base of each petiolule. It is of the trilacunar type when the foliar traces are caused from the stem. At the base of the swollen part of the petiole, three foliar traces, after stipular traces have left the lateral strands (Text-fig. 21, A), are fused into a continuous arc accompanied by six small bundles, on its chord, which are separated respectively from both margins of each trace (Text-fig. 21, B and C). Then the arc and these two bundles are fused into a continuous ring at a slightly higher level (Text-fig. 21, D and E). At the transitional region, between the pulvinus and the slender part of the petiole, a pair of ridge bundles emerge from the two closely neighbouring portions of the ventral side of this ring, so that there remains only a very minute segment of the ring between these two departing points of the ridge bundles (Text-fig. 21, F and G). The continuity of the stele is retained throughout the slender part of the petiole and internodes. In the transverse section through the middle of the petiole (Text-fig. 21, H), this continuous ring is composed of five segments (m , l_1 , l'_1 , l_2 , and l'_2) which are distinguished by the presence of the five groups of the protoxylem projected towards the pith; thus, the latter takes a pentagonal form. The vascular supply to each lateral leaflet respectively occurs from l_1 , l_2 , and l'_1 , l'_2 (Text-fig. 21, J-M). The fascicles for the stipel (st and st' in Text-fig. 21, J-L) are separated from the ridge bundles at this portion, but in the lower nodule this trace is very minute and difficult to discern. The ridge bundles in the internodes often furnish a few branches between the original two (Text-fig. 21, I). At the top of the rachis, the ridge bundles, after branching the fascicles for stipels, are inserted into two ventral portions of the continuous ring which, meantime, opens into an arc (Text-fig. 21, N and O). The bundle in the petiolule of each lateral and terminal leaflet represents an open arc in transverse section (Text-fig. 21, P).

Maackia amurensis RUPR. et MAXIM. var. **Buergeri** SCHNEID. (*Cladrastis amurensis* BENTH. var. *Buergeri* MAXIM.) [Text-fig. 21, Q]. Leaves, odd-pinnate;

leaflets, 3-6 paired. The vascular system in this species is nearly the same as in the former example. Text-fig. 21, Q shows the transverse section through the middle of the petiole. At each nodule the ridge bundles are divided into



Text-fig. 21. *Styphnolobium japonicum* (A-P, $\times 10$): A-G, pet. bas. (E, mid. of pulv.); H, pet. mid.; I, mid. of a lower internod.; J-M, a nod.; N, mid. of the highest internod.; O, top of the highest internod.; P, mid. of the petiolule of the terminal leaflet (St, stipular trace; st, stipular trace.). *Maackia amurensis* var. *Buergeri* (Q, $\times 10$): pet. mid. *Sophora angustifolia* (R-U, $\times 10$): R and S, pet. bas.; T, pet. mid.; V, mid. of a higher internod.

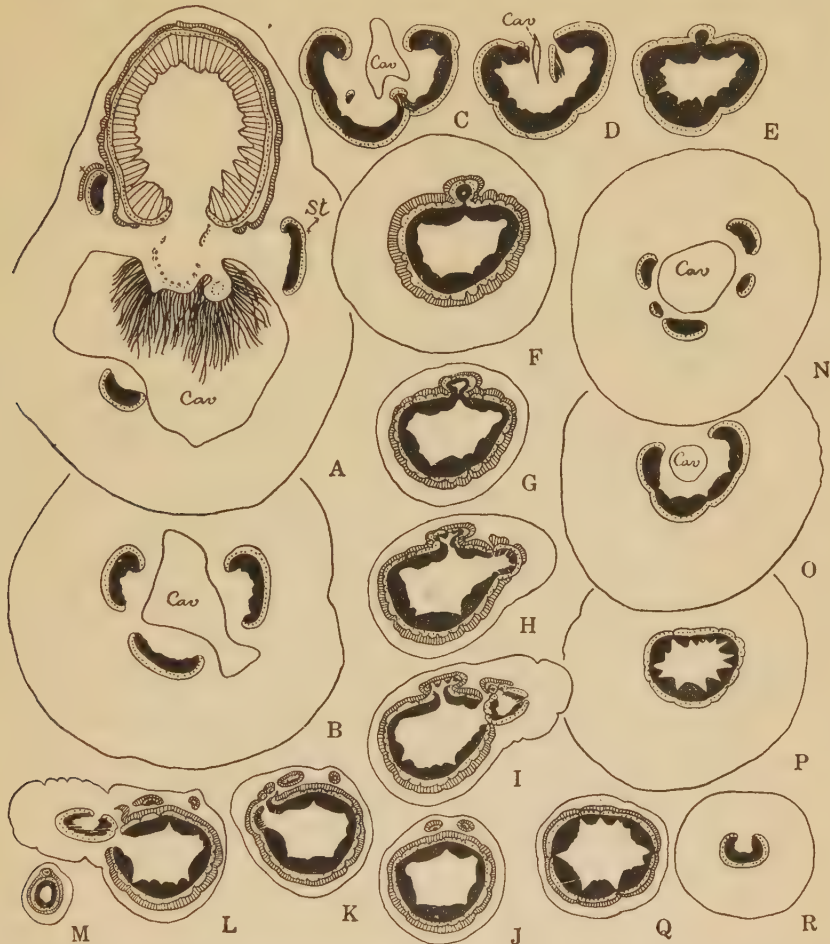
a certain number, a small portion of which is added to the trace for the lateral leaflet and, at the same time, each ridge bundle is connected by a few anastomosing bundles.

Ormosia formosana KANEHIRA [Pl. VI, figs. 23 and 24]. Leaves, odd-pinnate; leaflets, 5-9, paired. Three foliar traces are fused at the pulvinus into a continuous ring, the constitution being the same as in the former species. Such a continuous ring is invariably seen throughout the whole course of the petiole (Pl. VI, fig. 23) and rachis, except in the nodules. On each lateral part of this ring there is found a slightly thin portion from which at each nodule, the vascular supply for each lateral leaflet originates in the ordinary manner. At the higher internodule it takes a slightly winged condition and very minute fascicles for this wing are also supplied from the lateral projection of the ring, but they end blindly (Pl. VI, fig. 24). From the originating points of these bundles, it seems to be obvious that the lateral projected wing has a different meaning from the ridges which are usually found in other species.

Sophora angustifolia SIEB. et ZUCC. [Text-fig. 21, R-U]. Leaves, odd-pinnate; leaflets, many. At the base of the pulvinus, three foliar traces are fused into an arc accompanied by two small bundles on its chord (Text-fig. 21, R). These two bundles, which arise respectively from the portion where the three foliar traces are fused with each other, are fused respectively with each end of the arc, thus forming an arc having deeply curved ends (Text-fig. 21, S). At the base of the slender part of the petiole, a small portion of each end of the arc is separated, and these portions fuse into one which afterwards migrates to the ventral side. After this a small bundle, which soon divides into a few bundles, again emerges from the portion a little apart from each end of the arc. These small bundles occupy the normal position of the ridge bundles, and the bundle which emerges from the end of the arc is situated between these two ridge bundles. At the same time, the arc is divided into five main bundles and a few small ones, all of which are arranged in a circle, such a condition being seen throughout the slender part of the petiole (Text-fig. 21, T: represents the transverse section through the middle of the petiole). At the nodule, the ridge bundles and the bundle inset between them, anastomose with each other, but at the higher portion of the rachis the said bundles become thinner and thinner, until they finally fuse with the ridge bundles (Text-fig. 21, U).

Platyosprion platycarpum MAXIM. (*Cladrastis platycarpa* MAKINO) [Text-fig. 22, A-M]. Leaves, odd-pinnate; leaflets, 4-7 paired. At the base of the swollen part of the petiole, trilacunar foliar traces are arranged round the cavity including the intra-petiolar buds, and are fused into a continuous arc

near the upper part of the cavity (Text-fig. 22, A-D). As is usually the case, a pair of bundles emerge from the fusing points of three foliar traces (Text-fig. 22, C), each of which is fused respectively with each end of the arc (Text-



Text-fig. 22. *Platysprion platycarpum* (A-M, $\times 10$): A-F, pet. bas. (Cav., cavity for intra-petiole buds; St., stipular trace); G, pet. mid.; H, I, K, and L, nodes; J, mid. of the lowest internod.; M, mid. of the highest internod. *Cladrastis lutea* (N-R, $\times 8$): N-P, pet. bas. (Cav., cavity for intra-petiole buds.); Q, pet. mid.; R, mid. of the petiole of the terminal leaflet.

fig. 22, D). Then the arc is closed into a continuous ring at the middle of the pulvinus. One of the above stated bundles, however, is often extremely feeble, and, in rare cases, is altogether wanting (cf. the case of *Robinia hispida*). At the transitional region between the pulvinus and the slender part of the

petiole, a small amphicribal concentric ridge bundle emerges from the middle portion of the continuous ring, but, within the slender part of the petiole, the actual separation from the ring seldom occurs (Text-fig. 22, E-G).^{1), 2)} This condition suggests that the bundle which occurs at each nodule in the species of *Cæsalpinia* is in reality a special situation of the ridge bundle. At the lowest nodule, the ridge bundle shares off the branch which is joined with the strands for the leaflet (Text-fig. 22, H and I). In the internodes, a pair of normal ridge bundles are seen (Text-fig. 22, J), but at the higher internodes, these bundles are fused into one (Text-fig. 22, M). The constitution of the continuous ring in the petiole (Text-fig. 22, G) and internodes (Text-fig. 22, J), and the vascular supply to the leaflets (Text-fig. 22, H-L) are the same as in the case of *Styphnolobium japonicum*.

***Cladrastis lutea* RAFIN.** [Text-fig. 22, N-R]. Leaves, odd-pinnate; leaflets, 3-4 paired. Five foliar traces from pentalacunar gaps of the stem are supplied to the leaf, of which the pair next to the median strand is comparatively feeble (Text-fig. 46, E). At the base of the swollen part of the petiole, these five traces are arranged round the cavity of the intra-petiolar bud (Text-fig. 22, N). Differing from many examples hitherto described, so far as my observations go, no bundles issue from the fusing point of the three foliar traces, but they are directly fused into a continuous ring (Text-fig. 22, O and P). This continuous ring is soon dissected and such a condition is retained throughout the whole length of the petiole and rachis provided with no ridge bundles (Text-fig. 22, Q: showing the transverse section through the middle of the petiole). The vascular supply to a leaflet occurs from the lateral portion of this ring in the ordinary manner. At the top of the rachis, the ring opens to an arc and enters the terminal leaflet (Text-fig. 22, R).

[2] *PODARYRIÆ.*

***Thermopsis fabacea* DC.** [Text-fig. 23, A-G, and I-K; and Pl. VII, fig. 28]. Leaves palmately trifoliate; stipules, broad and leaflike. A few stipular bundles arise successively from each lateral of the trilacunar foliar traces. As described in *Cladrastis*, three foliar traces are directly fused into a continuous

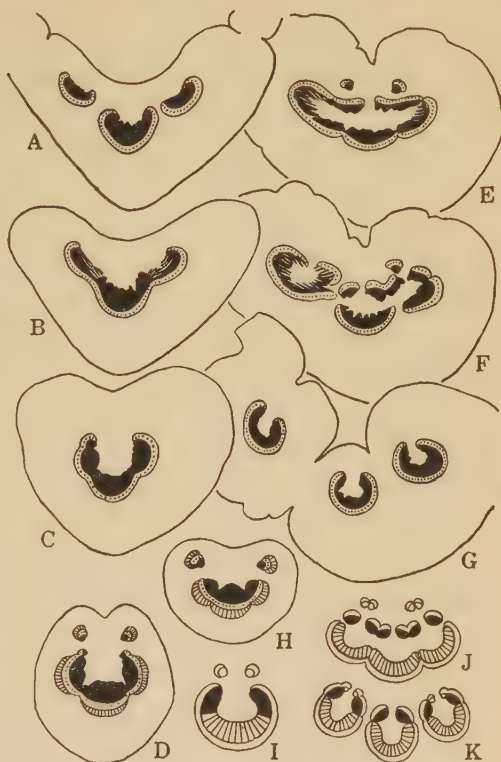
1) According to the description and illustration by PETIT (1887; p. 65 and Pl. IV, fig. 18), the same condition seems to be found in the petiole of *Toluifera Balsamum* MILLER.

2) In the case in which a complete separation of the ridge bundle occurs, this bundle is often divided into two as those in the internodes.

arc at the base of the petiole (Text-fig. 23, A-C). Meanwhile the somewhat broad base of the petiole gradually becomes cylindrical; ridge bundles are segmented from each end of the arc, so that in the middle of the petiole, a pair of ridge bundles and a continuous arc are seen (Text-fig. 23, D; and Pl. VII, fig. 28). At the top of the petiole, each end of the arc curves inwards to form a flat tened ellipse with a ventral opening (Text-fig. 23, E), the ventral half of which is then divided into six, and the dorsal half into three smaller arcs (Text-fig. 23, J and F). The ventral bundles are fused respectively with each end of the three dorsal arcs (Text-fig. 23, K). Thus, three bundles, each in the form of a deeply curved arc, are formed which respectively enter three palmate leaflets (Text-fig. 22, G), the ridge bundles being joined with the vascular supply for the lateral leaflets (Text-fig. 23, F and K).

Baptisia australis R. Br. [Text-fig. 23, H]. The vascular system in the petiole of a palmately trifoliolate leaf with large stipules, is nearly the same as that of *Thermopsis fabacea*, but at the middle of the petiole, the arc composed of bundles opens more widely than that of the former example (Text-fig. 23, H).

According to PETT's description (1887), in *Anagyris foetida* L. three foliar traces are fused into a continuous ring, at the base of the petiole, in the same manner as in *Cytisus Laburnum* L.



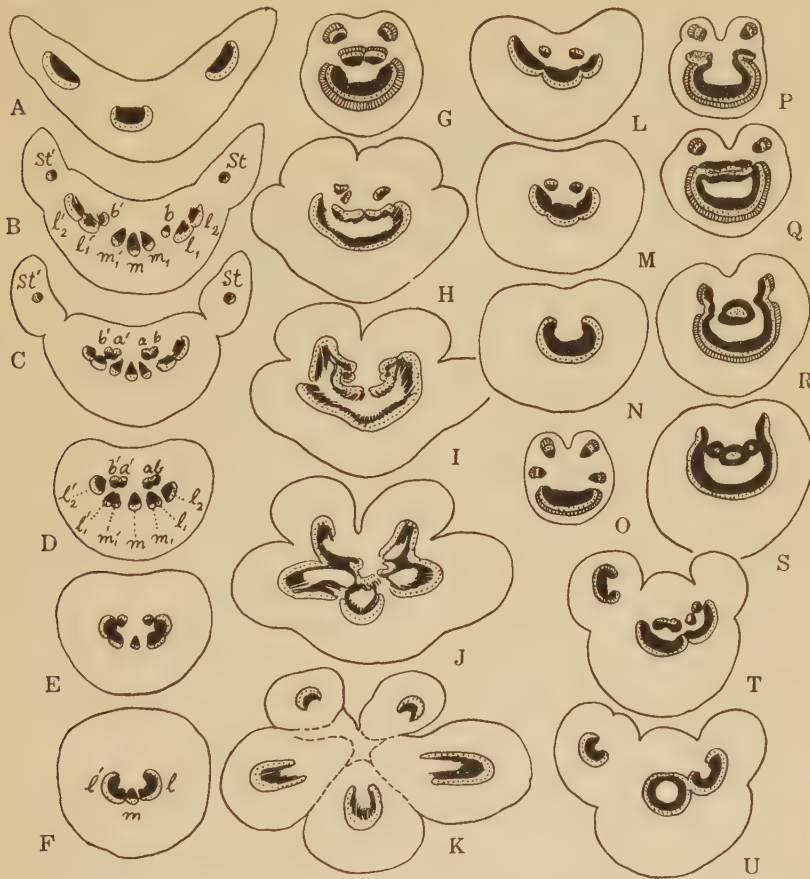
Text-fig. 23. *Thermopsis fabacea* (A-G, $\times 15$): A-C, pet. bas.; D, pet. mid.; E-G, pet. top.; I-K, diagrammatic representation of D, F, and G. *Baptisia australis* (H, $\times 10$): pet. mid.

[3] *GENISTEÆ*.

Crotalaria usaramoensis E. G. BAKER [Text-fig. 24, L-U; and Pl. VI, fig. 26]. Leaves, palmately trifoliate. This is trilacunar; a foliar trace is produced from each lateral gap, and three traces, of which the median one from the median gap is predominant in size, are soon fused into one. At the base of the pulvinus, these traces are fused into an open arc accompanied, on its chord, by two small bundles derived from the fusing points of the lateral and the median traces (Text-fig. 24, L and M), but a little higher up, these two are fused with each end of the arc (Text-fig. 24, N). A pair of ridge bundles and small lateral bundles are successively divided from both ends of the arc at the base of the slender part of the petiole, and this condition is maintained throughout the whole length of the petiole (Text-fig. 24, O; and Pl. VI, fig. 26: the transverse section through the middle of the petiole). Just below the top of the petiole, the small lateral bundles are again fused with the large median bundle thus forming a deeply curved arc. Both ends of the arc curve inwards, but then, in turn, the ends of the arc are folded outwards (Text-fig. 24, P). These folded ends are separated and are fused into a bar; meanwhile, the remaining portion of the arc becomes a continuous crescent (Text-fig. 24, Q); then the bar and the chord thus formed, fuse so as to form a small amphivasal ring; on the other hand, ridge bundles are fused respectively with each end of the arc of the crescent, so that, a continuous arc including a small ring is formed (Text-fig. 24, R). Higher up, the small ring is constricted into three ringlets, and the arc is also divided into three small arcs (Text-fig. 24, S and T); both halves of each ringlet are then fused respectively with the ends of each arc, thus forming three deeply curved arcs which are destined for the palmate leaflets (Text-fig. 24, U). In this way one can easily recognize that the disposition of bundles in the top of the petiole, though somewhat complicated, is fundamentally the same as *Thermopsis fabacea* (cf. Text-fig. 23, I-K).

Crotalaria sessiliflora L. [Text-fig. 24, A-F]. Leaves linear acute or lanceolate and short petiolate; stipules minute. The three foliar traces from the trilacunar gaps of the stem are present and separate in the slightly sheathing base (Text-fig. 24, A) and each lateral foliar trace furnishes a single fascicle for the stipule (*St* and *St'* in Text-fig. 24, B). Then the median trace is divided into three— m_1 , m , m_1' —and the lateral ones are divided respectively into l_1 , l_2 , and l_1' , l_2' (sometimes, the separation of the lateral foliar traces are incomplete); meanwhile, a minute bundle a is branched from m_1 , a' from m_1' ,

b from l_1 , and b' from l'_1 (Text-fig. 24, B and C); as they pass through the short petiole, m_1 , l_1 , l_2 , a , and b are fused into a single large lateral bundle l , and m'_1 , l'_1 , l'_2 , a' and b' , into l' (Text-fig. 24, D-F: E, middle of the petiole; F, top of the petiole).



Text-fig. 24. *Crotalaria sessiliflora* (A-F, $\times 18$): various levels of a short pet. *Crotalaria usaramoensis* (L-U, $\times 12$): L-N, pet. bas.; O, pet. mid.; P-U, pet. top. *Laburnum vulgare* (G-K, $\times 12$): G, pet. mid.; H-K, pet. top.

Laburnum vulgare J. PRESL. [Text-fig. 24, G-K]. The condition in the basal part of the petiole (trilacunar) is exactly the same as that of *Crotalaria usaramoensis*,¹⁾ while the condition in the top of the petiole shows a close

1) By PETTIT (1887), the successive transverse sections of the basal part of the petiole in *Laburnum vulgare* (*Cytisus Laburnum* L.) are illustrated and are reconstructed diagrammatically, showing that this type may be seen in many arborescent and frutescent species of this family (p. 55 and p. 171).

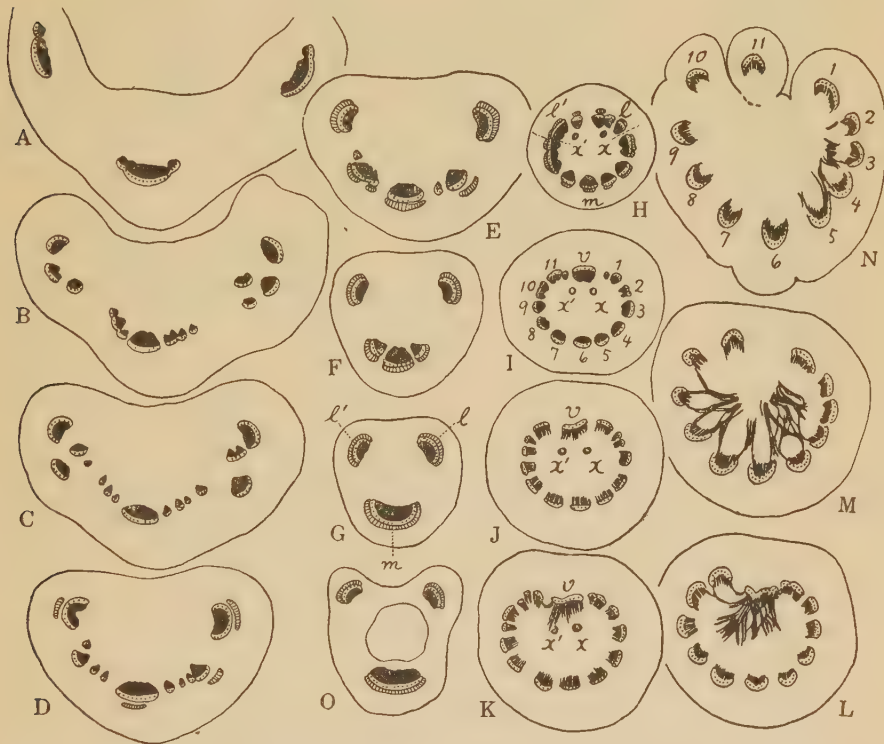
resemblance to that of *Thermopsis fabacea*. But the portion corresponding to the six bundles situated on the ventral side in *Thermopsis* is separated from the arc at the base of the slender part of the petiole, and is seen as a pair of bundles often fused into a single bundle situated on the chord of the arc through the whole slender part of the petiole (Text-fig. 24, G). Multiplication of the leaflets occurs frequently.¹⁾ In one of the examples with five leaflets, of which the outermost pair are somewhat smaller than the others, the arc in the petiole is divided into five bundles, to both margins of which a branch of the bundle situated on the arc chord is fused, the ridge bundles being connected with the bundles for the outermost leaflets (Text-fig. 24, G-K).

Lupinus hirsutus L. [Text-fig. 25, A-N; Text-fig. 26, A and B; Pl. VI, fig. 25; and Pl. VIII, figs. 44, 45, and 46]. Leaves palmately compound; leaflets, 5-15. The three foliar traces come out of the stem and enter a well-developed leaf-base in which they are arranged separately on an arc (Text-fig. 25, A). After a lateral trace has furnished a trace for the stipule, just above the part where the stipules become distinct from the petiolar base, the remaining lateral traces are divided into a few bundles, while the median trace puts out a few branches to both sides (Text-fig. 25, B). These bundles then migrate towards each other (Text-fig. 25, C-F; and Text-fig. 26, A), until in the slender part of the petiole, three bundles are seen arranged on a deeply curved arc (Text-25, G; and Pl. VI, fig. 25: middle of the petiole),—a median bundle *m* composed of the original median trace and a part of each lateral trace, and a pair of lateral bundles *l* and *l'* each of which is composed of the large part of the original lateral traces. At the higher part of the petiole, the median bundle is divided into several bundles, and the lateral bundles, into a few. All of these bundles are arranged on a circle, any neighbouring two of them anastomosing each other (Text-fig. 25, H), while a small amphivasal concentric bundle issues from each lateral bundle as medullary bundles (*x* and *x'* in Text-fig. 25, H-K). Finally, at the top of the petiole, there is seen a definite number of bundles corresponding to the number of leaflets, and a fairly large bundle *v* on the ventral side of the circle²⁾ (Text-fig. 25, I; and Pl. VIII, fig. 44: in Text-fig. 25, I,

1) The multiplication of the leaflets in this species is reported by VELENOSKÝ (1907; p. 495), who mentioned the cases of 4-5 leaflets and the transitional forms between these leaves and the normal palmately trifoliate ones.

2) TROLL (1932) described the relation between the peltation of the leaf in *Lupinus Cruckshanskii* A. GRAY and the unifacial structure of the higher portion of the petiole in this species.

the transverse section through the top of the petiole is shown, that case being represented when eleven leaflets are attached to the common petiole; the numerals 1-11 indicate the number of each leaflet, which numbers I shall use for convenience sake). The bundle *v* is composed of a large part of both *l* and *l'* and the bundles for 1 and 11 are respectively composed of a small part of *l* and *l'* to which often a small part of *m* is joined; the other bundles are furnished by the division of the median bundle. Just at the level where each



Text-fig. 25. *Lupinus hirsutus* (A-N, $\times 8$): A-F, pet. bas.; G, pet. mid.; H-N, pet. top. *Lupinus luteus* (O, $\times 10$): pet. mid.

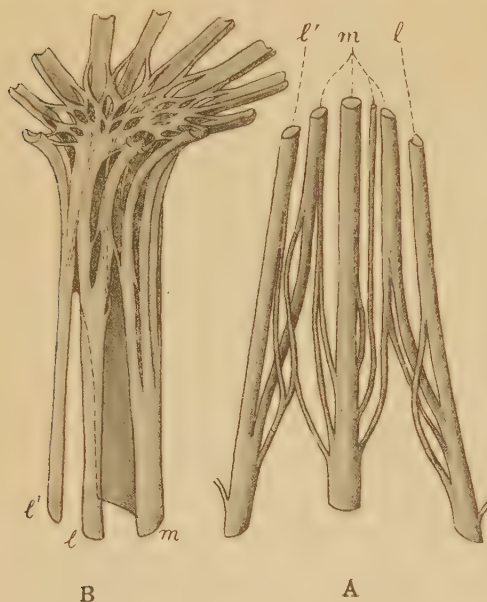
bundle enters the petiolule of the leaflet, the bundle *v* turns in a transverse direction to form a fan-like entanglement of the fascicles to which are fused the amphivasal concentric medullary bundles (*x* and *x'*) mentioned above; ultimately, these tangling fascicles are separated into many minute branches and are attached to both margins of each bundle for these eleven leaflets (Text-fig. 25, J-N; and Pl. VIII, figs. 44, 45, and 46). The condition on the petiolar top diagrammatically reconstructed is as shown in Text-fig. 26, B.

In *Lupinus luteus* L. the alternation of the relative position of the bundles at the petiolar base was never seen in the course of the present research. The constitution of three bundles in the slender part of the petiole (Text-fig. 25,

O) and the conditions at the petiolar top are altogether the same as in the case of *Lupinus hirsutus*.

PETIT'S observation on the *Lupinus* sp. (1887; p. 56) shows its similarity with these species.

Genista pilosa L. [Text-fig. 27, A-C]. Leaves, lanceolate or elliptical, and short petiolate, without stipules. Differing from the preceding examples, a single foliar trace comes out of a gap of the stem (Text-fig. 27, A), and passes, in the form of a widely open arc, through the petiole which occupies only a very short narrow portion between the leaf-base and the lamina (Text-fig. 27, B); at the top of the petiole a



Text-fig. 26. A, Diagrammatic reconstruction of the vascular system in the pet. bas. of *Lupinus hirsutus*. B, that in the pet. top of the same species.

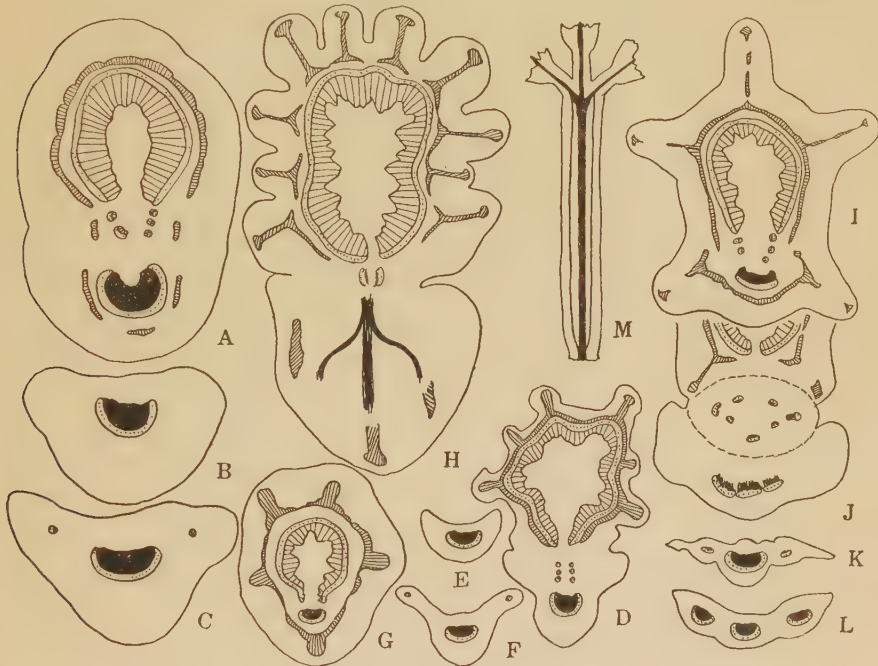
pair of minute bundles branch out from the margins of the bundle (Text-fig. 27, C). At the base of the lamina, the bundle is divided into three to form three main nerves.

The vascular systems in *Genista anglica* L. (Text-fig. 27, G) and *G. germanica* WILLD. (Text-fig. 27, D F) are the same as in the above-mentioned example. In the latter species the stem is provided with vertical ridges on its surface.

According to GRAVIS (1930), the palmately trifoliolate leaves, provided with a well-developed leaf-base, of *Genista radiatus* SCOP., are supplied by trilacunar foliar traces, but their further behaviours are not given by him.

Ulex europæus L. [Text-fig. 27, H]. Leaves spinescent, exstipulate. As was already reported by ACQUA (1887), a single foliar trace comes out from the gap, which in accordance with the sessile condition of the leaf, soon puts out a pair of lateral nerves (Text-fig. 27, H).

Cytisus Scoparius LINK. [Text-fig. 27, I-L; and Pl. V, fig. 2]. The leaves attached to the lower nodes of a shoot are palmately trifoliolate having rather a long petiole, while the leaves which are attached to the higher part reduce as a single sessile leaflet. Between these two conditions, there are found several sessile leaves having three leaflets. These are also unilacunar in vascular origin (Text-fig. 27, I; and Pl. V, fig. 2). In the case of the palmately tri-



Text-fig. 27. *Genista pilosa* (A-C, $\times 25$): A, node of stem; B, pet. mid.; C, bas. of lamina. *Genista germanica* (D-F, $\times 15$): D, node of stem; E, pet. mid.; F, bas. of lamina. *Genista anglica* (G, $\times 50$): node of stem. *Ulex europaeus* (H, $\times 25$): node of stem. *Cytisus Scoparius* (I-M) (I-L, $\times 10$; M, $\times 25$): I, node of stem; J, pet. bas.; K, pet. mid.; L, pet. top.; M, the whole vascular system.

foliolate leaf having the petiole, there are seen a large petiolar bundle and a pair of minute ridge bundles which branch out from the former at the base of the petiole (Text-fig. 27, K and M: fig. K, middle of the petiole). At the top of the petiole, the petiolar bundle is divided into three (Text-fig. 27, L), each of which enters a leaflet, and the ridge bundles are fused with the bundles for the leaflets (Text-fig. 27, M). In the sessile leaf having three leaflets, the foliar trace soon divides into three bundles, each of which enters the leaflet (Text-fig. 27, J). The case of the single leaflet is similar to the case of *Genista pilosa*.

[4] *TRIFOLIEÆ.*

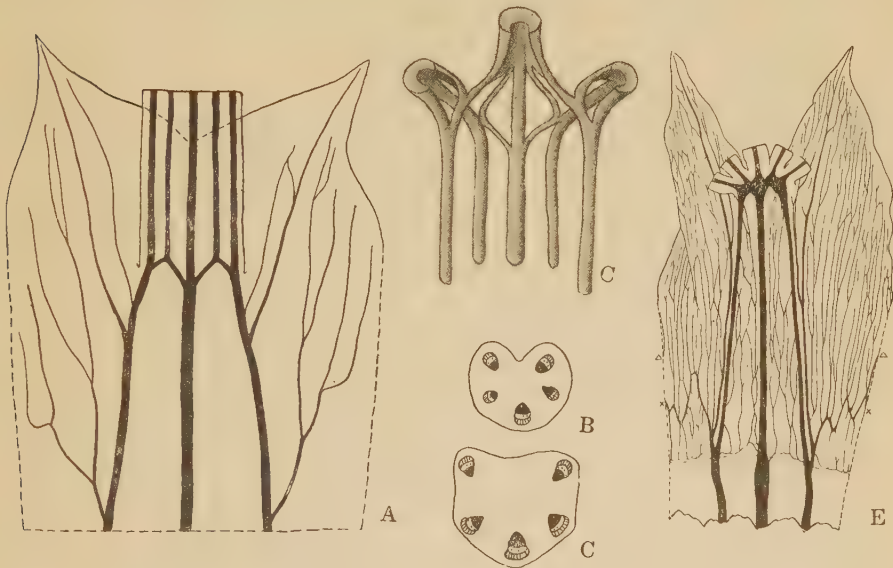
Trifolium repens L. [Text-fig. 28, A-C]. Leaves palmately trifoliolate. The broad stipules thoroughly embrace the stem to make a tubular sheath¹⁾ and their upper margins are fused in front of the ventral side of the petiolar base. This condition reminds us of the *ochrea* met with among *Polygonum*. The two laterals of the trilacunar foliar traces furnish fascicles for the stipules, and the median trace enters the petiolar base directly without branching. At the point where the stipule becomes distinct from the petiole, a branch from each lateral foliar trace and from both margins of the median foliar trace furnish two bundles inserted in the original three traces (Text-fig. 28, A). These five bundles are arranged in an arc which is invariably retained throughout the whole length of the long petiole (Text-fig. 28, B). In some cases, however, one of the above-mentioned two bundles is wanting and, occasionally, though very rarely, two of them are wanting, only three or four bundles existing in the petiole. But often the three foliar traces are connected by a fascicle at the basal part of the petiole from which no petiolar bundles originate. At the top of the petiole, these bundles enter the three palmate leaflets in the following manner (Text-fig. 28, C). At the top of the petiole, the median bundle furnishes a small branch for each lateral side; each branch is fused with one of the lateral bundles next to the median one, and enters the lateral leaflet together with the two bundles which successively branch off from the lateral bundle situated on the extremity of the arc in the petiole. The remains of the lateral and median bundles, the small fascicles from the branches of the median bundle and those of the feebler lateral bundles, are fused into a single strand which enters the median leaflet. Sometimes, however, there occur, as abnormal cases, four or five leaflets. In such cases the vascular supply to the leaflets situated between the median and ordinary lateral ones is only a repetition of the condition in the case of the lateral leaflet.

In *Trifolium pratense* L. the broad base of the petiole makes a pair of ordinary stipules. The vascular supply to these organs as well as the vascular system in the petiole are nearly the same as in the case of *Tr. repens* (Text-

1) Such a tubular sheath and the vascular supply for it in the same species are described by COLOMB (1887) and he pointed out the same condition in *Trifolium incarnatum* (p. 5 and 6), and approximately the same in *Onobrychis sativa* also (p. 7).

fig. 28, D: representing the transverse section through the middle of the petiole). The same conditions are also to be found at the top of the petiole.

In *Trifolium Lupinaster* L. the broad base of the petiole takes a tubular form as in the case of *Tr. repens*, but the upper margins are free to furnish a pair of ordinary stipules. The fascicles for the basal sheath and the stipules are supplied from the lateral foliar traces; and, unlike the former two examples, in the basal sheath, there is seen network of veinlets in the portion inserted between the three foliar strands (Text-fig. 28, E). Owing to the absence of the slender part of the petiole, the foliar strands furnish the vascular

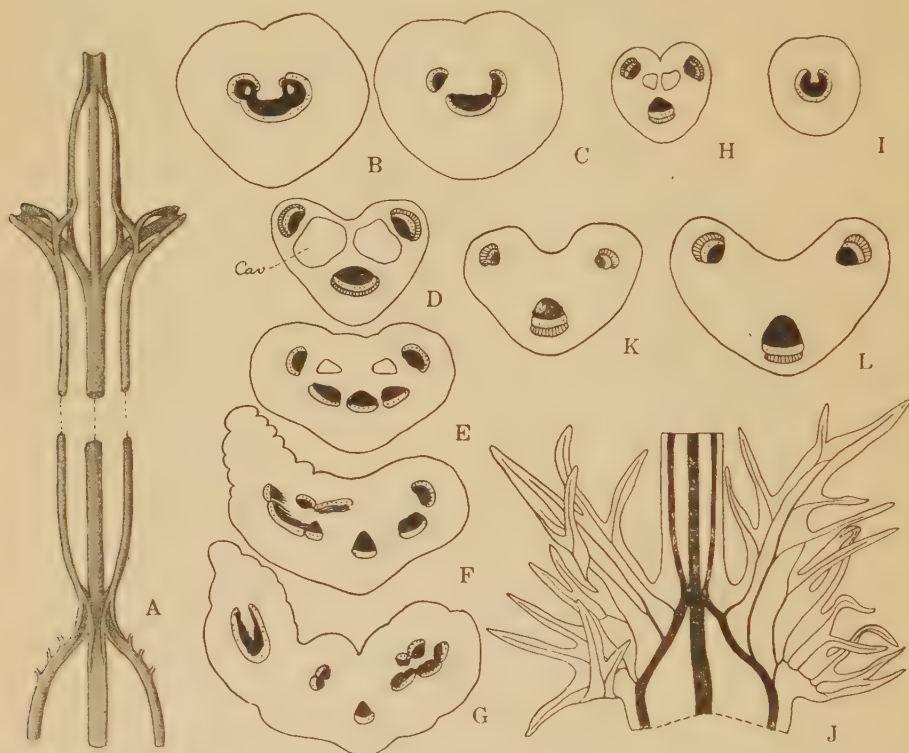


Text-fig. 28. *Trifolium repens* (A-C): A ($\times 12$), vascular system in the basal sheath and pet. bas.; B ($\times 12$), pet. mid.; C ($\times 25$), diagrammatic reconstruction of the vascular system in the pet. top. *Trifolium pratense* (D, $\times 10$): pet. mid. *Trifolium Lupinaster* (E, $\times 5$): whole vascular system.

supply for the leaflets directly, and this condition seems to show a close resemblance, (though without the elongated portion of the petiole), to the abnormal case in *Tr. repens* in which three petiolar bundles are seen. Moreover, the number of the leaflets which varies from three to five in this species shows also an intimate relation to the abnormal multiplication of the leaflets in the leaves of *Tr. repens*.

According to PETT (1887; p. 58), the same conditions are seen at the petiolar base and five bundles are present in the petiole, in *Tr. pratense*, *Tr. angusti-*

folium, and *Tr. subterraneum*, and he noticed even seven bundles in the petiolar top of *Tr. incarnatum*. From the figure representing the vascular course in the petiolar base of *Tr. pratense* illustrated by ACQUA (1887), one sees that three foliar strands which in normal cases are separated at the broad petiolar base seem to anastomose. The description of RIPPEL (1913) on the whole vascular course in the petiole of *Tr. elegans* SAVI. is almost similar to the



Text-fig. 29. *Melilotus suaveolens* (A-I) (B-I, $\times 15$): A, diagrammatic reconstruction of the whole vascular system; B and C, pet. bas.; D, pet. mid.; E-G, nod.; H, mid. of internod.; I, mid. of petiolute of the terminal leaflet. *Medicago denticulata* (J and K): J ($\times 12$), vascular system in pet. bas.; K ($\times 25$) pet. mid. *Medicago sativa* (L, $\times 25$); pet. mid.

case of *Tr. repens* treated in the present paper, though there are certain points of difference in regard to the condition of the vascular supply to the three leaflets, especially in the case of the lateral leaflets. He adds that the same condition is found in *Tr. pratense* and *Tr. pannonicum*.

***Melilotus suaveolens* LEDEB.** [Text-fig. 29, A-I]. Leaves pinnately trifoliate. The fascicles for the stipules are supplied from the lateral traces

coming out from the trilacunar gaps of the stem; three traces are then fused into an arc, and at the same time, from the point of fusion, a pair of small bundles separate off, to fuse with each end of the arc (Text-fig. 29, A and B); this arc then divides into three bundles—a large median and a pair of smaller lateral ones (Text-fig. 29, C), such a condition being retained throughout the whole length of the petiole (Text-fig. 29, D: middle of the petiole). Just below the nodule, the median bundle furnishes two large branches (Text-fig. 29, A and E); a large part of each branch enters the lateral leaflet together with two bundles that have issued from the lateral bundles, and each of the other lesser parts reinforce the lateral bundles of the rachis (Text-fig. 29, A-G); so that three bundles are also seen in the rachis (Text-fig. 29, H), which enter the terminal leaflet as a single strand in a small arc in transverse section (Text-fig. 29, I).

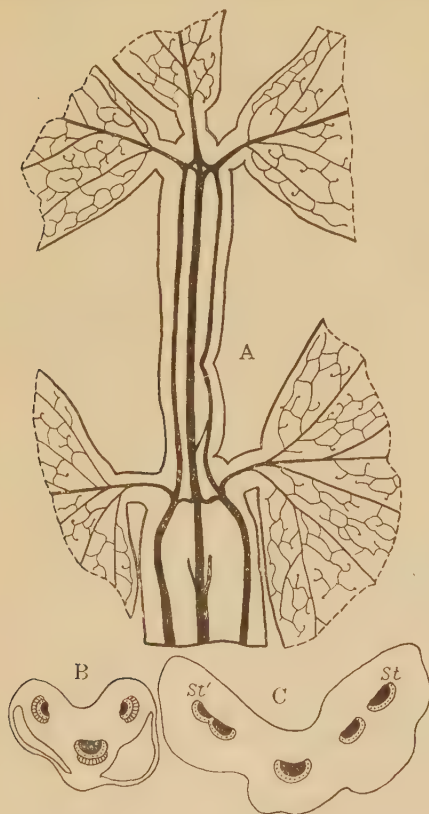
Medicago denticulata WILLD. [Text-fig. 29, J and K]. Leaves pinnately trifoliolate. A pair of prominent stipules are attached to the broad leaf-base in which three foliar traces are present, and the vascular supply to the stipules occurs successively from the lateral traces (Text-fig. 29, J). Though in the figure (Text-fig. 29, J) all details are obscured in solid black, the vascular system in the petiolar base, as well as in the other parts, is the same as in the case of *Melilotus suaveolens* (Text-fig. 29, K: middle of the petiole).

Also in the pinnately trifoliolate leaves of **Medicago sativa** L., the same vascular system is observed (Text-fig. 29, L: middle of the petiole). In this species, the leaf-base is somewhat better developed than in the former species.

PETIT attributes the vascular system in the petiole of *Melilotus parviflora* DESF., *Mel. officinalis*, *Medicago lupulina* L., and *Med. arborea* to the type of *Ononis Natrix* L. or *O. procurrens* WALLR. in which the three foliar traces are connected at the base of the petiole, but in the latter species, there are seen nine bundles in the slender part of the petiole through the division of each original bundle. WINTER (1932) described and illustrated the vascular system in the unifoliolate and trifoliolate leaves of *Medicago sativa*, and on the condition in the basal part of the petiole, he only stated, "the three traces anastomose at the point where the stipules become distinct from the petiole.....", while his description of the vascular supply to each leaflet, is that each lateral leaflet receives a branch of a lateral and median petiolar bundle and the terminal one, which is the remains of the lateral and median bundles.

[5] *LOTEÆ*.

Lotus corniculatus L. var. *japonicus* REGEL [Text-fig. 30, A-C]. Leaves are palmately trifoliolate and at the petiolar base there are a pair of large stipules which are often described as leaflets. Trilacunar. The whole vascular



Text-fig. 30. *Lotus corniculatus* var. *japonicus* (A-C): A ($\times 10$), the whole vascular system; B ($\times 20$), pet. bas.; C ($\times 20$), pet. mid.

system is rather simple (Text-fig. 30, A). At the base of the petiole, a branch issues from each lateral foliar trace and fuses respectively with a median strand¹⁾; the vascular supply to the leaflet-like stipules²⁾ (*St* and *St'*) occurs from the outer margins of the former (Text-fig. 30, B) at a point a little above the portion where the branches of the lateral traces are fused with the median foliar trace. At the top of the petiole, three bundles in the petiole (Text-fig. 30, C: middle of the petiole) supply the traces for two lateral leaflets as in the case of *Melilotus*³⁾ and, according to the morphological feature of the leaves, the remains of the bundles directly enter the median leaflet.

[6] *GALEGEÆ*.

Wistaria japonica SIEB. et ZUCC. (*Millettia japonica* A. GRAY) [Text-fig. 31, A-M]. Leaves, odd-pinnate; leaf-

1) According to PETIT's description on *Lotus corniculatus* L. "Je n'ai point observé d'anastomose", it seems that in this species there are no such branches in the case of the present variety. On the other hand, on the same species, ACQUA (1887) says, "I fasci laterali, dopo avere inviato un ramo alle stipule, si anastomizzano col fascio mediano".

2) VELENOVSKÝ (1907) treats these leaf-like stipules as "pseudo-stipules".

3) PETIT describes the vascular system of the petiole of *Anthyllis vulneraria* as being the same as that of *Lotus corniculatus*, and he adds, ".....seulement on trouve à la caractéristique cinq faisceaux au lieu de trois". It seems obvious that the three bundles between the outermost ones are furnished by the division of the median petiolar bundle.

lets, 5-7 paired. The highest internodule is often extremely short, and, therefore, the terminal leaflet and the pinnate leaflets at the highest nodule represent a palmate appearance. Trilacunar. Three foliar traces are fused into a continuous ring, after passing through the same process as in *Styphnolobium japonicum* (Text-fig. 31, A-C). At the transitional region between the pulvinus and the slender part of the petiole, the continuous ring opens to form a



Text-fig. 31. *Wistaria japonica* (A-M, $\times 10$): A-E, pet. bas.; F, pet. mid.; G-J, a nod.; K, mid. of the highest internod.; L, top of the highest internod.; M, mid. of the petiolule of the terminal leaflet. *Wistaria floribunda* (N, $\times 10$): pet. mid. *Wistaria venusta* (O, $\times 10$): pet. mid. *Wistaria sinensis* (P, $\times 10$): pet. mid. *Millettia reticulata* (Q and R, $\times 10$): Q, pet. mid.; R, mid. of a higher internod. *Glycyrrhiza echinata* (S, $\times 25$): pet. mid.

deeply curved arc, both ends of which detach as a pair of ridge bundles; at the same time, the arc divides into three large and two small bundles (Text-fig. 31, D and E). Each of the latter soon divides into a few much smaller ones, and this topographical condition continues throughout the whole slender part of the petiole (Text-fig. 31, F: middle of the petiole). The transverse section through the successive vascular course at the nodule is somewhat complex (Text-fig. 31, G-J). Just below the nodule, the vascular supply

to the lateral leaflet occurs from the middle portion of each lateral bundle and, at the same time, the small bundles reinforce the lateral bundle. There are found no peculiarities in the constitution of the traces for the lateral leaflet. Each half of a pair of lateral bundles situated on the ventral side tends to fuse into a single large one, so that there results a condition recalling that of a nodule in *Albizzia Julibrissin*; but this single bundle soon divides into two, retaining the original constitution. The lateral bundles, which are divided into two by the vascular supply, are soon fused into one and a few bundles are segmented from the margin next to the median bundle. On the other hand, the ridge bundles which anastomose with each other send fascicles to the traces for the leaflet and remaining part enters the stipel (Text-fig. 31, G and H). The same condition is repeated from nodule to nodule and internodule to internodule, but in every nodule, except a few lower ones, the branches from the median bundle reinforce the lateral bundles which have decreased in size. At the top of the rachis, large parts of the ridge bundles enter a pair of stipels, and that which remains is inserted into the middle portion of each lateral bundle (Text-fig. 31, L); all bundles are then fused into an arc (Text-fig. 31, M) which enters the terminal leaflet.

The vascular system in the petiole and rachis of *Wistaria floribunda* DC. (Text-fig. 31, N), *W. venusta* DC. (Text-fig. 31, O), and *W. sinensis* DC. (Text-fig. 31, P), all with odd-pinnate leaves consisting of 6-8 pairs of leaflets, may be classed in the same category, but in these species the bundles corresponding to the smaller lateral bundles in *W. japonica* are slightly more numerous, while in the latter two species, the petiolar bundles tend to fuse in a continuous, dissected, ring.

Millettia reticulata BENTH. [Text-fig. 31, Q and R]. Leaves, odd-pinnate, leaflets, 2-4 paired. Though the petiolar bundles are fused into a continuous ring, the portions corresponding to the three large bundles of *Wistaria japonica* may be clearly seen (Text-fig. 31, Q). In the higher internodes, however, they are observed as three large separated bundles and a few small ones (Text-fig. 31, R).

Glycyrrhiza echinata L. Leaves, odd-pinnate, consist of 2-3 pairs of leaflets, with the highest internode extremely short. The vascular system is the same as *Wistaria japonica* (Text-fig. 31, S: middle of the petiole).

The vascular system and the morphological features of the leaves of *G. foetida* DESF. and *G. Dubia* BERNH. are the same as the former example. PETIT (1887) described the condition in the basal part of the petiole of *G. glabra* as being the same as that of *Cytisus Laburnum* (*Laburnum vulgare*).

Amorpha fruticosa L. [Text-fig. 32, A]. Leaves odd-pinnate, leaflets, 5-10 paired. There are five bundles, nearly equal in size, and a pair of ridge bundles in the slender part of the petiole (Text-fig. 32, A); the vascular supply to the lateral leaflets is taken from these two pairs of lateral bundles. Both ends of a leaflet strand which represents an arc in the transverse section, are



Text-fig. 32. *Amorpha fruticosa* (A, $\times 25$): pet. mid. *Indigofera incarnata* (B, $\times 25$): pet. mid. *Indigofera Kirilowii* (C, $\times 25$): pet. mid. *Indigofera pseudo-tinctoria* (D, $\times 25$): pet. mid. *Indigofera Dosua* (E, $\times 25$): pet. mid. *Robinia pseudacacia* (F, $\times 25$): pet. mid. *Robinia hispida* (G-L, $\times 16$): G-K, pet. bas.; L, pet. mid. *Millettia taiwaniana* (M-R, $\times 6$): M, pet. mid.; N-R, nod. *Tephrosia candida* (S, $\times 12$), pet. mid.

from one of the lateral petiolar bundles situated on the ventral side, and the middle portion from the other lateral petiolar bundle near the median bundle. From these facts, one can easily recognize that a pair of large lateral bundles in *Wistaria japonica* nearly correspond to two pairs of lateral bundles in this species. On the other hand, in the present species it frequently occurs that the two lateral bundles on the same side are fused into a single large bundle.

Splendid examples of such cases are also seen in other tribes, namely *Cassieæ* (on which I have already described in the preceding pages, cf. 255 sqq.) and *Hedysaræ* (especially among the species of *Lespedeza*).

Indigofera incarnata NAKAI [Text-fig. 32, B; and Pl. VI, fig. 18]. Odd-pinnate leaf consisting of 6–10 pairs of leaflets. The whole vascular system, except for the absence of the ridge bundles, is the same as *Amorpha fruticosa* (Text-fig. 32, B and Pl. VI, fig. 18: middle of the petiole).

Indigofera Kirilowii MAXIM. Odd-pinnate leaf consisting of 3–6 pairs of leaflets; here also there are no ridge bundles, and, though all the petiolar bundles are fused into a continuous ring, the portions corresponding to five bundles are easily discerned by the presence of protoxylem groups projecting towards the pith and by the crowded condition of the conducting elements (Text-fig. 32, C: middle of the petiole).

Indigofera pseudo-tinctoria MATSUM. Odd-pinnate leaf consisting of 4–6 pairs of leaflets; there are three main bundles throughout the petiole and internodes (Text-fig. 32, D: middle of the petiole); the vascular supply to the lateral leaflets occurs in the same manner as in *Wistaria japonica*.

Indigofera Dosua BUCH.-HAM. Leaves, odd-pinnate; leaflets, 6–10 paired; there are a pair of ridge bundles and a continuous ring in which the segments corresponding to the three bundles are clearly seen (Text-fig. 32, E).

Robinia pseudacacia L. [Text-fig. 32, F]. Leaves, odd-pinnate; leaflets, 4–9 paired. Stipules, spiny. Here also the five main bundles are seen in the petiole, in addition to a few small bundles between them (Text-fig. 32, F). At the nodule, many inserted small bundles are fused with main bundle, so that there are seen five large bundles as in the case of *Amorpha fruticosa*. No peculiarities are found in the vascular supply to each leaflet. The ridge bundles, originated, at first as a single bundle from the middle portion of the ventral side of the continuous ring in the pulvinus, are divided into two (Pl. VIII, figs. 38 and 39).

At the petiolar base of **Robinia hispida** L. (leaves odd-pinnate; leaflets, 3–6), I often found some abnormalities, as the few cases observed in *Platyosprion platycarpum* (cf. p. 267). In the usual case, a pair of small bundles issue from the fusing portion of each foliar trace to the ventral side, and then all the bundles are fused into a continuous ring (Text-fig. 32, G–I); but there often occurs a single bundle (Text-fig. 32, J), and sometimes, though rarely, a case without any bundles (Text-fig. 32, K). But in any case, a continuous ring is formed at a higher level, in which, at the slender part of the petiole

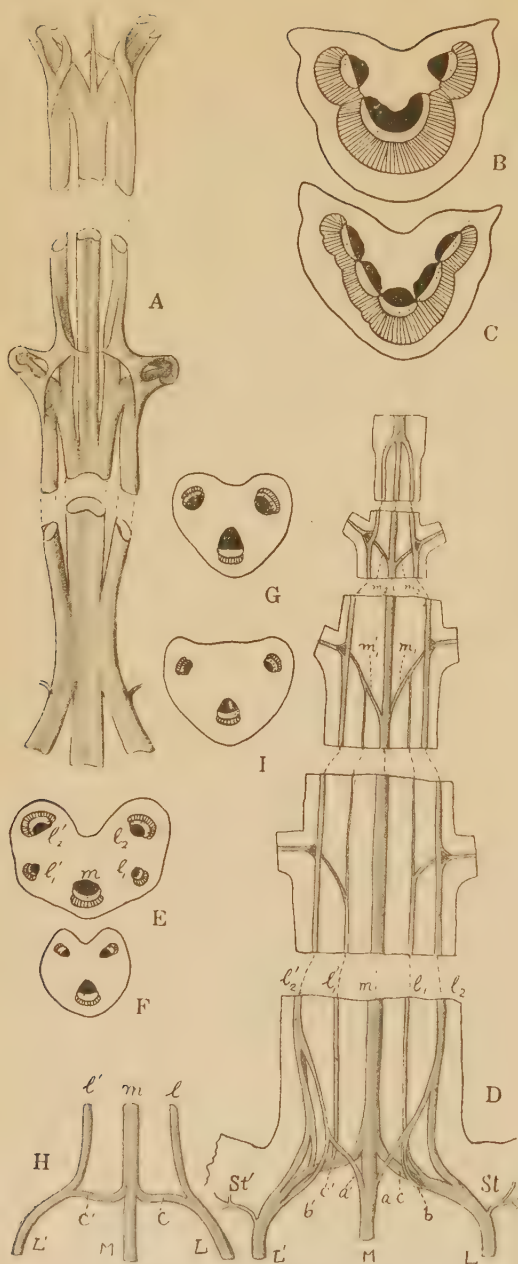
and in the rachis, are seen the five portions corresponding to the five bundles in former examples (Text-fig. 32, L). These five portions, however, are separated into five bundles at each nodule; so that the same condition is seen as in the case of *Robinia pseudacacia*.

Millettia taiwaniana HAYATA [Text-fig. 32, M-R]. Leaves, odd-pinnate, leaflets, 6-7 paired. The continuous ring as in the case of *Robinia hispida* is seen throughout the whole length of the petiole and rachis (Text-fig. 32, M). A large portion of each ridge bundle enters a lateral leaflet and the reduction of the size of each ridge bundle in the next internode is reinforced by the small bundle which separates from the ventral portion of the ring, just below the nodule (Text-fig. 32, N-R). The same conditions are repeated at each nodule.

Tephrosia candida DC. [Text-fig. 32, S; and Pl. VII, fig. 30]. Leaves, odd-pinnate; leaflets, 8-12 paired. In the slender part of the petiole and at every internode, there are three large bundles in which two lateral bundles often fuse to form a single large arc, and each ridge bundle frequently divides into a few small branches (Text-fig. 32, S; and Pl. VII, fig. 30). The condition in each nodule is the same as in the case of *Millettia taiwaniana*.

Caragana Chamlagu LAM. [Text-fig. 33 A-C; and Pl. VII, fig. 27]. Leaves even-pinnate with spiny stipules and spiny terminal appendage. Leaflets, 2 paired.¹⁾ The whole vascular system in the petiole and rachis is shown in a diagram (Text-fig. 33, A). Three foliar traces are directly fused into a continuous arc at the base of the petiole as in the case of *Thermopsis fabacea*, but immediately after, this arc is divided into three bundles—a large median bundle and two smaller lateral ones. The same condition is seen in the transverse section through the middle of the petiole (Text-fig. 33, B; and Pl. VII, fig. 27). At a level just below the lower nodule the median petiolar bundle is divided into three, so that there forms an open arc consisting of five bundles, nearly equal in size (Text-fig. 33, C). These five bundles have the same significance as those of *Amorpha fruticosa*, at the nodule. So far as the condition in this nodule is concerned, it is the same as that of *Melilotus suaveolens* already

1) I occasionally found an abnormal case in which the leaflet is segmented into two, of which the terminal segment represents the form of a deep cup, and the lower segment represents a shallow one; these two segments are often separated by an elongated stalk. This condition is altogether the same as the well-known example—*Codiaeum variegatum* L. In a few cases moreover, the leaflet takes the form of a shallow cup. Such abnormality is reported by VELENOVSKÝ (1907; p. 412 and 413), among the leguminous plants, in *Vicia sepium*.



Text-fig. 33. *Caragana Chamlagu* (A-C, $\times 30$): A, diagrammatic reconstruction of the whole vascular system; B, pet. mid.; C, pet. top. *Astragalus reflexistipulus* (D-F, $\times 25$): D, diagrammatic reconstruction of the whole vascular system; E, pet. mid.; F, mid. of a higher internod. *Astragalus adsurgens* (G, $\times 25$): pet. mid. *Astragalus sinicus* (H and I, $\times 25$): H, vascular system in pet. bas.; I, pet. mid.

mentioned in the preceding pages (cf. p. 278). In the internode, three bundles are also seen, of which the median one is predominant in size. Just below the upper nodule, the median bundle is divided into two large bundles and a smaller and feebler one, the latter entering the terminal appendage together with a pair of small fascicles, each of which is a branch from each lateral bundle respectively, while each of the two large bundles enters each leaflet together with each lateral bundle; so that the constitution of the strands for each leaflet is exactly the same as in the case of those attached to the lower nodule.

According to PETIT (1887), the vascular system in *Psolaria stachydis* L. and *Colutea arborescens* seems to belong to one of the above-mentioned cases, and in *Galega officinalis*, he observed fifteen separated bundles arranged on a circle. ACQUA's description of the vascular systems in *Wistaria rubra* HORT., *W. chinensis* DEC., and *Robinia pseudacacia* L. also agrees with what I have observed.

Astragalus reflexistipulus MIQ. [Text-fig. 33, D-F]. Leaves, odd-pinnate leaflets, 5-7 paired.

Stipules, large, membranous, and are fused with their basal parts to form a tube, for which a single fascicle branches from each lateral foliar trace (*St* and *St'* in Text-fig. 33, D), and soon divides into many veinlets. At the base of the petiole, a pair of small fascicles branch from the median foliar trace (*a* and *a'*) and the small branches (*b* and *b'*)¹⁾ respectively from the lateral foliar traces *L* and *L'* (Text-fig. 33, D); at the same time, the lateral traces are each divided into two bundles, a pair of which offers a pair of lateral petiolar bundles *l*₂ and *l*_{2'}; other ones (*c* and *c'*), which run nearly in a transverse direction, join to the median foliar strand, after a pair of small lateral bundles *l*₁ and *l*_{1'} branch, to form a median petiolar bundle *m* (Text-fig. 33, D and E). The fascicles *a* and *b* are fused with *l*₂, and *a'* and *b'* with *l*_{2'}. The vascular supply to the lowest leaflets occurs from *l*₁ and *l*₂ (or *l*_{1'} and *l*_{2'}) in the normal manner; in many cases, at the nodule on the next higher level, *l*₁ (or *l*_{1'}) is joined to the branch from the median bundle (*m*₁ or *m*_{1'} in Text-fig. 33, D); to this the branches of the lateral bundle *l*₂ (or *l*_{2'}) combine in order to form the vascular supply to the lateral leaflet. In the higher internodes, a pair of lateral bundles are seen and a large median bundle (Text-fig. 33, F), while at the nodule, the vascular supply to the lateral leaflets occurs from the lateral and median bundles (Text-fig. 33, D).

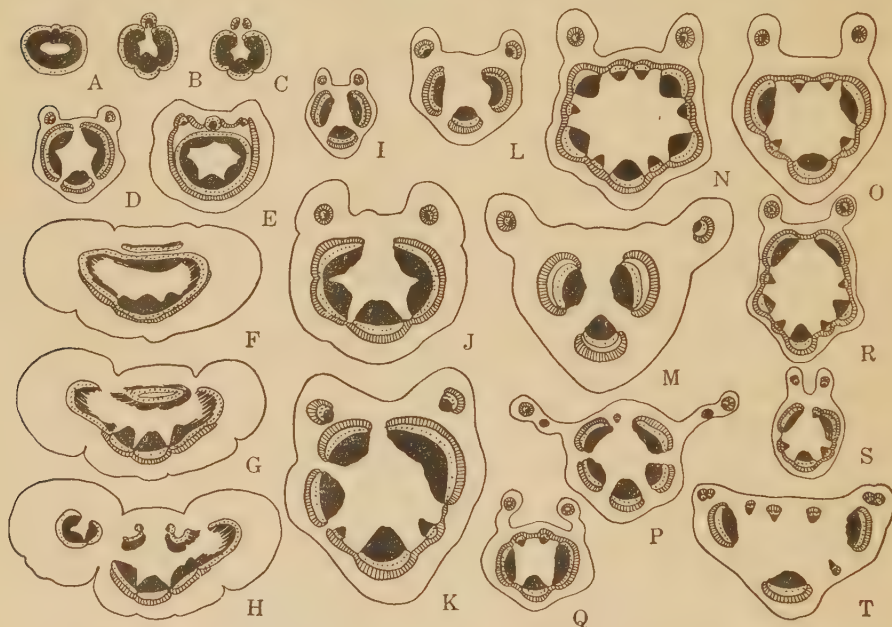
***Astragalus adsurgens* PALL** [Text-fig. 33, G]. Leaves odd-pinnate; leaflets, 5-10 paired. Stipules, separated. The condition in the basal part of the petiole is the same as that of *A. reflexistipulus*, except in regard to the absence of the bundles corresponding to the *l*₁ and *l*_{1'}; so that the conditions in the slender part of the petiole (Text-fig. 33, G: middle of the petiole), and in the internodes, and the nodules are the same as those in the higher nodules of the former example.

***Astragalus sinicus* L.** [Text-fig. 33, H and I]. Leaves, odd-pinnate; leaflets, 4-8 paired. The vascular system in the basal part of the petiole is simpler than in the former examples; that is, the median and lateral foliar traces are connected only by the branches (*c* and *c'*) of lateral ones (Text-fig. 33, H). The rest of the vascular system is the same as the case of *A. adsurgens* (Text-fig. 33, I: middle of the petiole).

1) In Text-fig. 33, D, the bundles *b* and *b'* are each illustrated as a single bundle for the sake of convenience, but actually, each one is observed to be a group of very minute fascicles.

[7] *HEDYSAREÆ*.

Lespedeza tomentosa SIEB. [Text-fig. 34, A-I; Text-fig. 35, A; Pl. VII, fig. 29]. Leaves, pinnately trifoliolate. The whole vascular system in the petiole and rachis is represented diagrammatically in Text-fig. 35, A. The condition in the petiolar base is exactly the same as in former examples (e. g. *Wistaria*, etc.). The ridge bundle appears first as a single bundle from the ventral portion of the continuous ring at the transitional region between the pulvinus and the slender

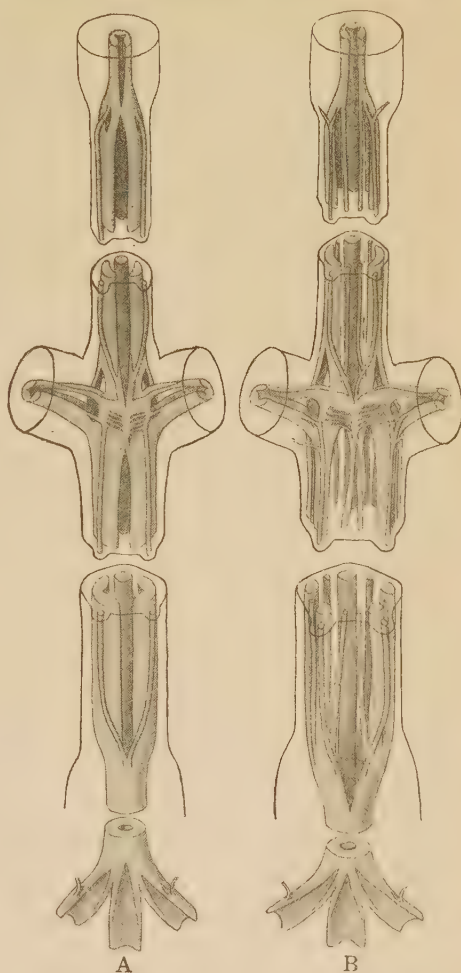


Text-fig. 34. *Lespedeza tomentosa* (A-I, $\times 12$): A-C, pet. bas.; D, pet. mid.; E-H, nod.; I, mid. of internod. *Lespedeza Buergeri* (J, $\times 25$): pet. mid. *Lespedeza nikkoensis* (K, $\times 25$): pet. mid. *Lespedeza pilosa* (L, $\times 30$): pet. mid. *Lespedeza serpens* (M, $\times 50$): pet. mid. *Desmodium racemosum* (N and O): N ($\times 10$), pet. mid.; O ($\times 20$), mid. of internod. *Desmodium caudatum* (P and Q, $\times 25$): P, pet. mid.; Q, mid. of internod. *Desmodium Oldhami* (R and S, $\times 8$): R, pet. mid.; S, mid. of the higher internod. *Desmodium gyrans* (T, $\times 25$): pet. mid.

part of the petiole, and is then divided into two, just as in the case of *Robinia pseudacacia* (Text-fig. 34, A-C). On the other hand, the continuous ring is divided into a median bundle and a pair of large lateral bundles which are often segmented respectively into two, and this condition is retained throughout the slender part of the petiole (Text-fig. 34, D; and Pl. VII, fig. 29: the transverse section through the middle of the petiole); but, just a little

below the nodule, the petiolar bundles are fused into a continuous ring, in which the original three bundles are clearly observed by the segmentation of the ring (Text-fig. 34, E). Then, a small bundle issues from the ventral portion of this ring and the vascular supply to each lateral leaflet arises from the middle portion of each lateral bundle in the ordinary manner (Text-fig. 34, E-G). In this case, the small bundle just mentioned anastomoses with the ridge bundles, a large portion of which joins with the vascular supply to the lateral leaflet; both margins of each half of the lateral bundles situated on the ventral are folded to the ventral, to form an entangled vascular complex which joins the small bundle mentioned above (Text-fig. 34, E-G; and Text-fig. 35, A). A pair of new ridge bundles appear from the vascular complex at a higher level (Text-fig. 34, H). The nature in *Millettia taiwaniana* and *Tephrosia candida* is the same as the present case. At the internodule, a median bundle again forms, together with a pair of large lateral bundles (Text-fig. 34, I), all of which enter the terminal leaflet as a single strand which represents an arc in transverse section.

In *Lespedeza Buergeri* MIQ. (Text-fig. 34, J; and Pl. VI, fig. 15), *L. nikkoensis* NAKAI (Text-fig. 34, K), *L. pilosa* SIEB. et ZUCC. (Text-fig. 34, L), *L. cuneata* G. DON, *L. serpens* NAKAI (Text-fig. 34, M), the same condition is seen, though in the latter three species the internodule is often extraordinarily short; in the former two species, there is frequently seen a case in which each lateral bundle is divided into two dis-



Text-fig. 35. A, diagrammatic reconstruction of the whole vascular system of *Lespedeza tomentosa*. B, that of *Desmodium racemosum*.

tinct bundles (Text-fig. 34, K; and Pl. VI, fig. 15: showing respectively the transverse section through the middle of the petiole in *L. nikkoensis* and *L. Buergeri*; a lateral bundle is single and large, while the other one is divided into two).

Desmodium racemosum DC. [Text-fig. 34, N and O; Text-fig. 35, B; Pl. V, fig. 3; and Pl. VI, fig. 14]. Leaves, pinnately trifoliolate. The few first-formed leaves are almost always supplied with three foliar traces from the trilacunar gaps of the stem, but in the more vigorous leaves formed later, the traces often come out from four or five distinct gaps (see Text-fig. 46, G and F). Such an additional trace, which is often very feeble, issues from a gap inserted between the median gap and one of the ordinary lateral ones, but the position of this gap seems indefinite, being situated, in some cases, close to the median gap, and, in others, near the lateral one. In any cases, these additional traces are joined to the lateral traces preceding to fuse with the median one. Text-fig. 35, B represents the whole vascular system in the petiole and rachis, showing the case of three gaps. The condition in the basal part (Pl. V, fig. 3: middle of the pulvinus) and nodule is altogether the same as those of *Lespedeza tomentosa*. In the slender part of the petiole, however, there is a median bundle, two pairs of lateral bundles which correspond to a pair of large lateral bundles in the former examples, and a few small ones (Text-fig. 34, N; and Pl. VI, fig. 14), while in the internodule, the remains of these two pairs of lateral bundles fuse into a pair of large lateral ones as in the case of *Lespedeza tomentosa* (Text-fig. 34, O). In this species, marked stipelar traces branch out from the ridge bundles.

Exactly the same conditions are seen in **Desmodium podocarpum** DC. var. **indicum** MAXIM.

In **Desmodium caudatum** DC., each leaf seems to be always supplied with five foliar traces. The two pairs of lateral foliar strands, however, are fused into a pair preceding to fuse with the median strand. The remaining conditions are the same as those of *D. racemosum* (Text-fig. 34, P and Q: showing respectively the transverse section through the middle of the slender part of the petiole and that of the internodule).

The odd-pinnate leaves consisting of 2-3 pairs of leaflets of **Desmodium Oldhami** OLIV. are always supplied by five foliar traces. The topographical disposition of the bundles in the petiole and internodules, except the uppermost one, are exactly the same as that in the petiole of *D. racemosum* (Text-fig. 34, R: the middle of the petiole), while in the uppermost internodule, it

is the same as in the internodule of *D. racemosum* (Text-fig. 34, S). The condition in each nodule is also the same as the former example.

In *Desmodium gyrans* DC., the lateral leaflets are frequently much reduced and in such cases the traces for these are also very feeble. The vascular system is similar to the case of *Lespedeza tomentosa* (Text-fig. 34, T: middle of the petiole). According to PETIT (1887; p. 61), the disposition of the petiolar bundles of *Desmodium canadense* is the same as that of *Desmodium gyrans*.

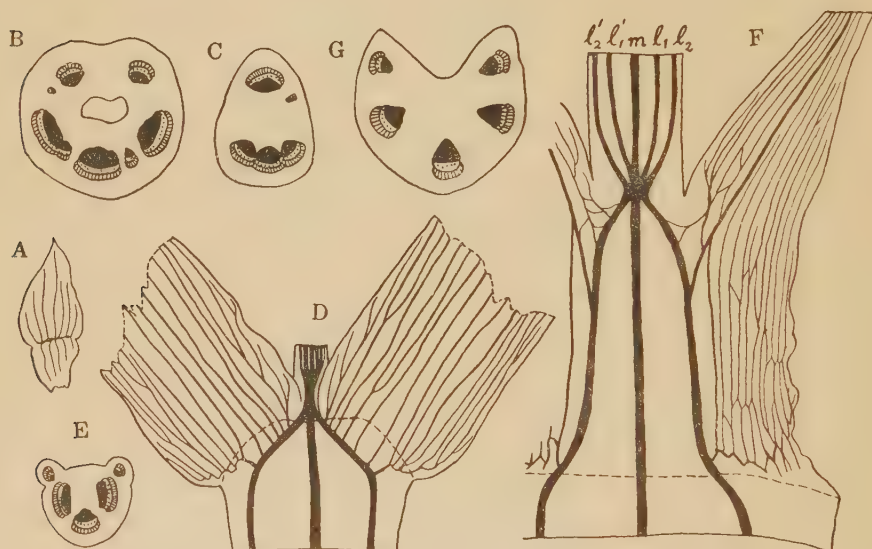
Aeschynomene indica L. [Text-fig. 36, A-C]. Leaves even-pinnate; leaflets, numerous (20-30 paired). Each stipule consists of upper and lower lobes (Text-fig. 36, A), the vascular supply to which occur from each lateral foliar trace (such a type of stipules are frequently observed in *Phaseoleæ*).¹⁾ At the basal part of the petiole, three foliar traces are fused into a continuous arc, accompanied by a pair of small bundles as in the case of many former examples. Soon, each small bundle is fused with each end of the arc, to form an incurved arc, which is divided into five distinct bundles at the transitional region between the pulvinus and the slender part of the petiole, such a condition being retained throughout the slender part of petiole and the lower internodule (Text-fig. 36, B: middle of the petiole). The vascular supply for the lateral leaflet takes place in the ordinary manner, and the same condition is repeated from nodule to nodule. In this species there are seen neither ridge bundles in the slender part of the petiole and internodes, nor an entangled vascular complex in the nodule. In the higher internodes, a pair of lateral bundles, which are situated far from the median petiolar bundle, tend to fuse into a single bundle, and the median bundle and a pair of lateral bundles next to the median one, into an incompletely fused one (Text-fig. 36, C). This topographical disposition resembles that of some mimosoideous species, e. g. *Mimosa spegazzinii*, *Acacia sphærocephala*, etc.

Kummerowia striata SCHINDLER [Text-fig. 36, D and E]. Leaves palmately trifoliate with large and membranous stipules to which the lateral foliar traces successively furnish many veinlets (Text-fig. 36, D). Then, three foliar traces are fused into a continuous ring at the point where the stipules become distinct from the petiole, in the same manner as in the case of *Caragana Chamlagu* (*Galegeæ*) or *Thermopsis fabacea* (*Podalyrieæ*); but in the petiole

1) Also this two-lobed stipules appear in *Zornia*. Many examples (*Zornia latifolia* DC., *Z. trachycarpa* VOG., etc.) are illustrated by MALME (1931).

they are seen as a median bundle and a pair of large lateral bundles. The topographical disposition of the petiolar bundles is thus the same as in the case of *Lespedeza tomentosa*, (Text-fig. 36, E). At the top of the petiole, the traces for each lateral leaflet are furnished from each lateral bundle, and those for the median leaflet, from the median and lateral petiolar bundles. No vascular complex on the ventral side is seen, though the lateral bundles anastomose with one another at this point.

Arachis hypogæa L. [Text-fig. 36, F and G; and Pl. VI, fig. 21]. Leaves even-pinnate (leaflets, 2 paired) having an eminent leaf-base to which a pair of large



Text-fig. 36. *Aeschynomene indica* (A-C): A ($\times 3$), stipule; B ($\times 25$), pet. mid.; C ($\times 25$), mid. of a higher internod. *Kummerowia striata* (D and E): D ($\times 10$), vascular system in pet. bas.; E ($\times 25$), pet. mid. *Arachis hypogæa* (F and G): F ($\times 5$), vascular system in the sheathing base of pet.; G ($\times 10$), pet. mid.

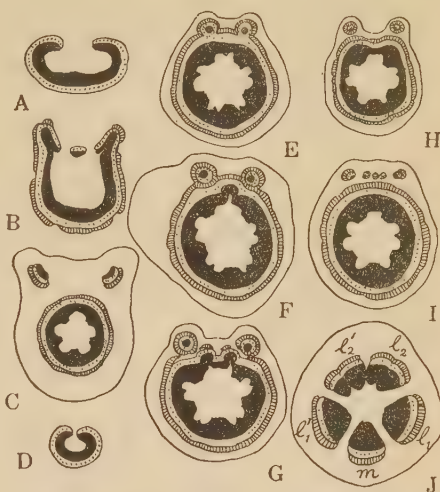
membraneous stipules are attached. The stipular traces occur from the lateral foliar traces, and this condition shows a remarkable resemblance to the case of *Trifolium Lupinaster* (Text-fig. 36, F). The three traces are directly fused into a continuous arc at the petiolar base as in the case of *Kummerowia striata*. In the petiole, however, there are seen five distinct bundles (Text-fig. 36, G; and Pl. VI, fig. 21). No peculiarities are found in the vascular supply to the lateral leaflets, but at the top of the rachis, all bundles enter the leaflet. There is no terminal appendage.

[8] *DALBERGIEÆ*.

***Euchresta japonica* BENTH.** [Text-fig. 37, A-D; and Pl. VI, fig. 22]. Leaves, pinnately trifoliolate. The condition in the basal part of the pulvinus is the same as that of *Lespedeza tomentosa*. In this species, through the whole length of the pulvinus there is seen a deeply curved arc (Text-fig. 37, A). At the transitional region between the pulvinus and the slender part of the petiole, both ends of the arc are segmented to form a pair of ridge bundles, and, at the same time, there appears a small bundle which is soon fused with the arc into a continuous ring (Text-fig. 37, B); in this, the portions corresponding to the five bundles in many former examples, are discerned by the presence of five groups of the protoxylem (Text-fig. 37, C; and Pl. VI, fig. 22: middle of the petiole). The condition in the nodule is nearly the same as that of *Lespedeza tomentosa*, while in the internodule there is also seen a continuous ring. The bundle in the petiolule of the leaflet represents a deeply curved arc in transverse section (Text-fig. 37, D).

***Pongamia glabra* VENT** [Text-fig. 37, E-G; and Pl. VII, fig. 36]. Leaves, odd-pinnate; leaflets, 2 paired. The whole vascular system is the same as that of *Millettia taiwaniana* (Text-fig. 37, E: middle of the petiole). The small bundle which issues from the ventral portion of the ring just below the nodule is ectocribal and concentric (Text-fig. 37, F), and such a bundle is not always single but may be two small ones, between which a small segment of the ring is left (Text-fig. 37, G; and Pl. VII, fig. 36).

***Derris elliptica* BENTH.** [Text-fig. 37, H]. The odd-pinnate leaf consisting of 5-7 pairs of leaflets presents the same external morphological features as that of *Glycyrrhiza* sps. or that which frequently occurs in *Wistaria japonica*; namely, the internodule between the terminal leaflet and the highest nodule is



Text-fig. 37. *Euchresta japonica* (A-D, $\times 10$): A and B, pet. bas.; C, pet. mid.; D, mid. of petiolule of the terminal leaflet. *Pongamia glabra* (E-G, $\times 10$): E, pet. mid.; F and G, just below two different nods. *Derris elliptica* (H, $\times 6$): pet. mid. *Pterocarpus indicus* (I, $\times 10$): pet. mid. *Dalbergia Sissoo* (J, $\times 30$): pet. mid.

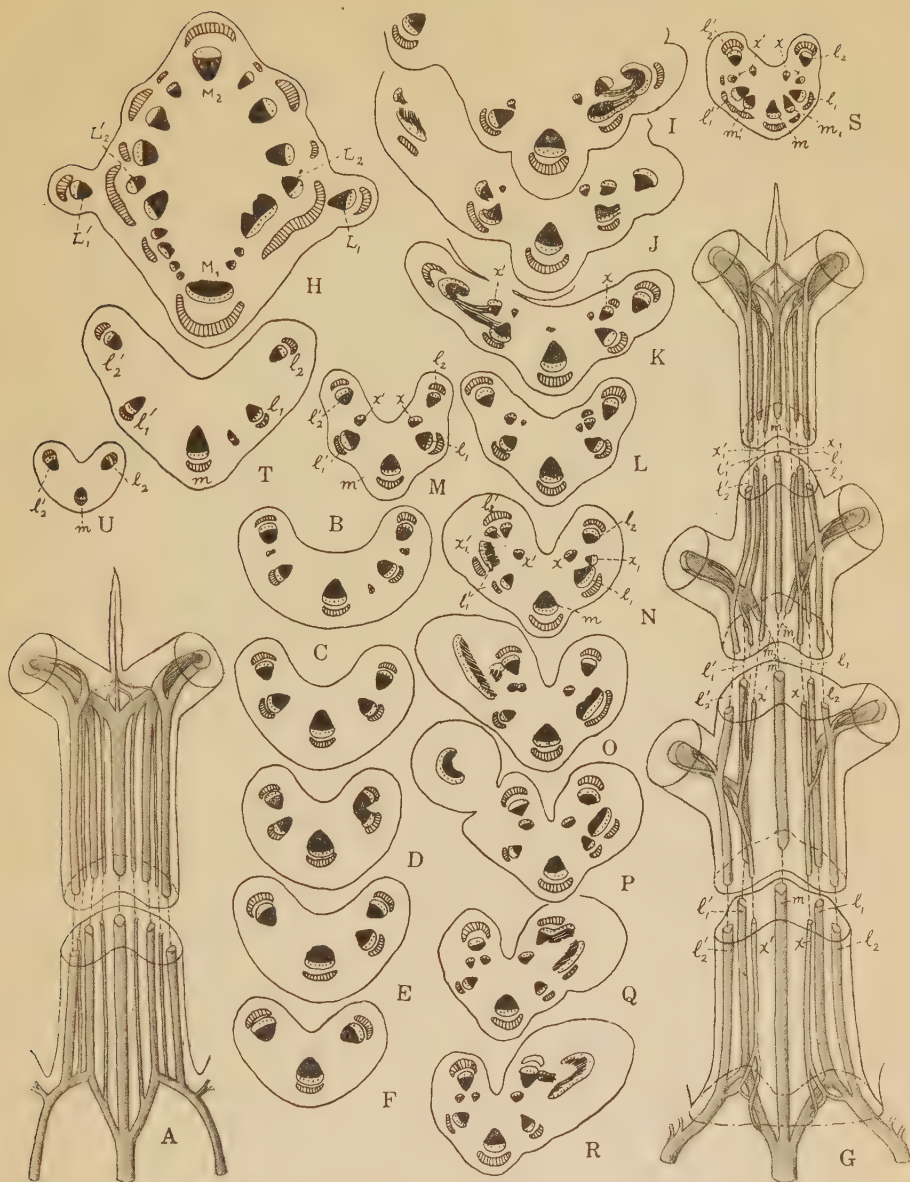
extremely short. The whole vascular system is the same as in the case of *Millettia taiwaniana* (Text-fig. 37, H: middle of the petiole). The bundle which is caused from the ventral side of the ring at each nodule is always single within the extent of my observation.

***Pterocarpus indicus* WILLD.** [Text-fig. 37, I]. Leaves, odd-pinnate; leaflets, 3-5 paired. In most cases, the number of the foliar traces is three, but cases with four gaps are observed though rarely. The whole vascular system is the same as in the case of *Styphnolobium japonicum*. The ridge bundles are often divided into many at the slender part of the petiole as has already been seen in *Maackia amurensis* var. *Buergeri* (Text-fig. 37, I: middle of the petiole).

***Dalbergia Sissoo* ROXB.** [Text-fig. 37, J]. Leaves, odd-pinnate; leaflets, 2-3 paired. Trilacunar. The condition in the basal part of the petiole is the same as in the former examples. In the slender part, five separated bundles m , l_1 , l'_1 , l_2 , l'_2 are seen (Text-fig. 37, J). But, often, m , l_1 , and l'_1 , and l_2 and l'_2 , are respectively fused to form a large open and dissected arc on the dorsal side, and a single large bundle which is also dissected into two (rarely into four) on the ventral side. No peculiarities are found in the nodule.

[9] VICIÆ.

***Vicia unijuga* AL. BR.** [Text-fig. 38, A and B; and Pl. VI, fig. 20]. A pair of leaflets are attached to the petiolar top, with a minute terminal appendage between them. Stipules are large and foliar. Trilacunar. The median foliar trace is separated from the vascular circle of the stem at the node, and each lateral one is separated from the stem at a node below, running up through an internode as the cortical bundle, which is often called the stipular bundle (cf. Text-fig. 38, H). The whole vascular system in the petiolar base, the slender part of the petiole, and the petiolar top is represented in a diagram (Text-fig. 38, A). Five large bundles, arranged on an open arc, are seen in the slender part of the petiole (Text-fig. 38, B; and Pl. VI, fig. 20: middle of the petiole); three of these consist respectively of the original three traces, while the two, situated between them, are respectively formed by the fusion of branches of a median trace and that of a lateral one. Besides these five large bundles, there are a few minute bundles which issue from the branches of the median and lateral traces, but their number is indefinite; they are rarely completely absent, however. At the petiolar top, the median bundle is divided into two large bundles, leaving a small bundle between them; each of these



Text-fig. 38. *Vicia unijuga* (A and B): A ($\times 10$), diagrammatic reconstruction of the whole vascular system; B ($\times 15$), pet. mid. *Vicia bifolia* (C-F, $\times 15$): mid. of several different petioles. *Vicia nipponica* var. *typica* (G-S, $\times 15$): G, diagrammatic reconstruction of the whole vascular system; H, node of the stem; I-L, pet. bas.; M, pet. mid.; N-R, the lowest nod.; S, just below the 2nd nod. *Vicia sativa* (T and U, $\times 15$): T, pet. mid.; U, mid. of a higher internod.

unites with a neighbouring lateral bundle and some minute ones, and enters each leaflet together with each outermost lateral bundle. Thus there is formed a bundle, for a leaflet, which represents an arc in transverse section, both marginal portions of which originate from an outermost lateral bundle. Though the constitution of the bundles for the terminal appendage is the same as that of the median leaflet in the case of *Trifolium repens*, they are very feeble and are, except in the case of the median one, often difficult to discern.

The external morphological features and the vascular system in the leaves of *Vicia bifolia* NAKAI are nearly the same as in the former example. No minute bundles are seen within the extent of my present investigation (Text-fig. 38, C). At the basal part of the petiole, the following cases, which are never observed in *V. unijuga*, are sometimes found though rarely; in consequence of the extreme shortness of one or both of the branches from the lateral foliar strands, two lateral bundles on the same side approach each other closely in the slender part (Text-fig. 38, D); in extreme cases, only three bundles are seen (Text-fig. 38, F) produced by the fusion of each branch of the median trace and each lateral one.

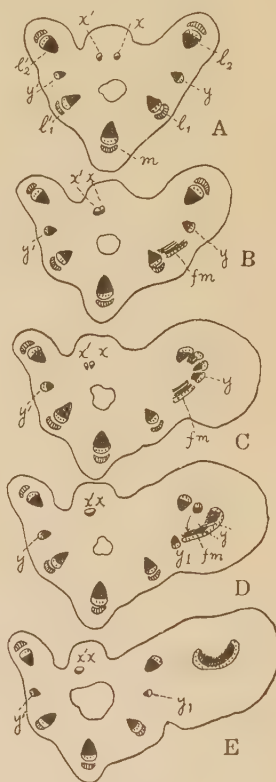
***Vicia nipponica* MATSUM. var. *typica* NAKAI** [Text-fig. 38, G-S]. Leaves, even-pinnate; leaflets, 2-3 paired. Stipules, large and leaf-like, to each of which a few fascicles are supplied from each lateral foliar strand. As is represented in diagrammatical reconstruction showing the case of three pairs of leaflets (Text-fig. 38, G), the whole vascular course in the petiole and rachis is a little more complicated than in the former examples. Five large bundles (m , l_1 , l'_1 , l_2 , l'_2) which are arranged on an open arc in the slender part of the petiole (Text-fig. 38, M) are formed by the same process as in the case of *Vicia unijuga*; but on the chord of the arc, a pair of rather small bundles (x and x') are seen, each of which is formed by the fusion of a few branches of the median foliar strand and a branch of a lateral one at the basal part of the petiole, where the formation of a pair of lateral petiolar bundles (l_1 and l'_1) occurs simultaneously (Text-fig. 38, H-L). One can easily recognize that the bundles x and x' are the same, in their nature, as the pair of small bundles which arose from the fusing points of the foliar strands in many preceding examples. Just below the lowest nodule, the vascular supply to the lateral leaflets, which are attached on levels a little apart, occurs respectively from l_1 and l_2 , and l'_1 and l'_2 . At the same time, each of the bundles (x and x') furnishes a branch (x_1 and x'_1) which is fused with the bundles for a lateral leaflet (Text-

fig. 38, G and N-R). Except for the fact that the lateral bundles (l_1 and l_1') which are decreased in size are reinforced by the branches (m_1 and m_1') of the median bundle (m), the condition in the next nodule (Text-fig. 38, G and S) is exactly the same as that in the lowest nodule, in which the median bundle is altogether independent from the vascular supply to the leaflets. The condition at the top of the rachis is the same as that of *Vicia unijuga* except for the presence of the bundles x and x' (Text-fig. 38, G).

Vicia sativa L. [Text-fig. 38, T and U]. Leaves, even-pinnate; leaflets, 5-10 paired. The condition in the basal part of the petiole is the same as that of *Vicia unijuga*. In the petiole and a few lower internodes, there are five large (m , l_1 , l_1' , l_2 , l_2') and a few small bundles, arranged on an open arc (Text-fig. 38, T). Except for the absence of the bundles corresponding to x and x' , in many nodules, and a few higher ones, the vascular supply to the lateral leaflets occurs in the same manner as has already been described in the case of *Vicia nipponica* var. *typica*. In a few higher internode, however, there are three bundles (Text-fig. 38, U) which correspond to m , l_2 , and l_2' , and the vascular supply to a leaflet occurs from these three.

The same vascular system is represented by **Vicia hirsuta** KOCH and **Vicia tetrasperma** MOENCH.

Vicia Faba L. [Text-fig. 39, A-E; and Pl. VI, fig. 19]. Leaves even-pinnate. Often, only a pair of leaflets are seen; in such cases, the vascular system in the petiole is exactly the same as that of *Vicia unijuga*, with no bundles on the ventral side. But in many vigorous leaves, there are seen a few pairs of leaflets which, the terminal leaflets excepted, are often attached alternately; in such cases, the vascular system shows a marked resemblance to that of *Vicia nipponica* var. *typica*. At the petiolar base, however, a part of the bundle corresponding to x in *Vicia nipponica* var. *typica* is fused with a minute bundle originating from the branch of a lateral foliar trace which forms, together with that from the median foliar trace, one



Text-fig. 39. *Vicia Faba* (A-E, $\times 12$): A, pet. mid.; B-E, nod.

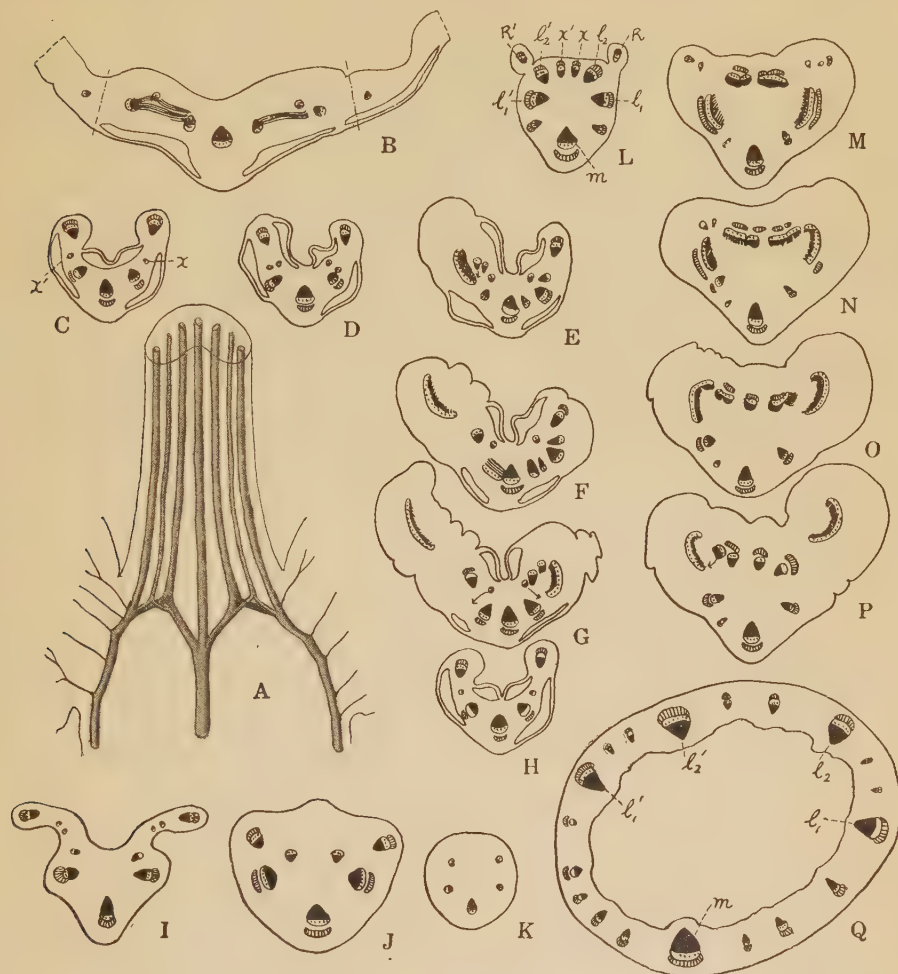
of the lateral bundles l_1 ; thus there is formed the bundle y situated between l_1 and l_2 (Text-fig. 39, A; and Pl. VI, fig. 19); the corresponding bundle y' is also formed by the same process. At a nodule (Text-fig. 39, B-E), the bundle y (and y') goes out to the leaflet together with a branch fm from l_1 and two branches from l_2 , while the bundle x (and x') situated on the ventral side has no relation to the vascular supply, blindly ending at a certain level of the rachis. The bundle y (Text-fig. 39, D and E) which is situated between l_1 and l_2 in the next internodule issues from fm .

ACQUA (1887) reported that the bundles on the ventral side of the petiole in *Vicia Faba* were seen only in leaves having a few pairs of leaflets, and that they were wanting in leaves having a smaller number of leaflets. His observations on the condition in the petiolar base are the same as my own, though he gave no account as to the origin of the bundles on the ventral side. According to PETIT's (1887) illustration, though no precise description is given, several other species of *Vicia* besides *Vicia Faba*, namely, *Vicia angustifolia* ROTH, *V. dumetorum* L., *V. allissima*, and *V. sativa*, seem to belong to the same category which is represented by *Vicia unijuga* or *V. Faba* in the present study. GERRESHEIM's observation (1913) on *Vicia Faba* showing the case of two pairs of leaflets, somewhat differs from mine; that is, the lateral bundles l_2 and l_2' are formed from the lateral foliar strands and the bundles m , l_1 , l_1' , y and y' , from the median one, and he says, "Der Blattgrund, der an den anderen Typen, z. B. *Clematis*, *Erodium*, u. a. eine Stelle wichtiger Bündelverbindungen ist, enthält bei *Vicia* nur eine Bündelspattung; —". But his observations on the vascular supply to the leaflets are in accordance with mine. Also he stated that the same vascular system was seen in *Amicia zygomeres* (Hedysareæ), *Lathyrus vernus*, and *Clanthus puniceus* (Galegeæ).

Lathyrus vernus KUNTH [Text-fig. 40, A-H]. Leaves, even-pinnate, leaflets, 2-3 paired. The condition in the basal part of the petiole is the same as in the case of *Vicia nipponica* var. *typica* (Text-fig. 40, A and B), but the bundles corresponding to x and x' are situated on the arc in the slender part of the petiole (Text-fig. 40, C: middle of the petiole). At the nodule, however, these bundles migrate to the ventral side, and a branch which enters the lateral leaflet issues from each of these bundles (Text-fig. 40, D-G). So that, in this region, the topographical disposition of the bundles is exactly the same as that of *Vicia nipponica* var. *typica*, while in the internodes, these bundles again take their original position (Text-fig. 40, H). The constitution of the vascular supply to the terminal appendage is the same as that of *Vicia*.

The vascular system in the petiole and rachis of *Lathyrus palustris* L. var. *linearifolius* SER. is the same as that of the above mentioned example.

Lathyrus maritimus BIGEL var. *glaber* FERNALD [Text-fig. 40, J and K]. An even-pinnate leaf, consisting of 3-6 pairs of leaflets, with the rachis



Text-fig. 40. *Lathyrus vernus* (A-H, $\times 15$): A, diagrammatic reconstruction of the vascular system in pet. bas.; B, pet. bas.; C, pet. mid.; D-G, nod.; H, mid. of a internod. *Lathyrus palustris* var. *linearifolius* (I, $\times 25$): I, pet. mid. *Lathyrus maritimus* var. *glaber* (J, $\times 15$): J, pet. mid.; K, tendril. *Lathyrus Davidii* (L-P, $\times 12$): L, pet. mid.; M-P, nod. *Pisum sativum* (Q, $\times 12$): pet. mid.

elongated into a tendril. The vascular system is the same as that of *Vicia nipponica* var. *typica* (Text-fig. 40, J: middle of the petiole). In the tendril,

there are seen only five bundles arranged on a deeply curved arc (Text-fig. 40, K).

Lathyrus Davidii HANCE [Text-fig. 40, L-P]. An even-pinnate leaf having a tendril; leaflets, 3-4 paired. The main five bundles (m , l_1 , l'_1 , l_2 , l'_2) arranged on a deeply curved arc and a pair of small bundles (x and x') on the chord of the arc in the petiole, are formed by the same process which has already been described in the case of *Vicia nipponica* var. *typica* (Text-fig. 40, L). The vascular supply to the lateral leaflets occurs normally. Differing from many preceding examples, the bundles (x and x') on the chord have no direct relation to the vascular supply for the leaflet, but they reinforce the lateral bundles l_2 and l'_2 at each nodule (Text-fig. 40, M-P). In this species, there is seen a pair of ridge bundles which issue from l_2 and l'_2 , and their behaviour is the same as those of many preceding examples. The disposition of the bundles in the tendril is the same as in the case of *Lathyrus maritimus* var. *glaber*.

According to PETIT (1887; p. 62), in *Lathyrus sphaericus* RETZ, the topographical disposition of the petiolar bundles is the same as in *Lathyrus vernus*, but he never comments on the behaviour of the small bundles corresponding to x and x' . ACQUA (1887; p. 58) stated that the vascular system in *Lathyrus nodosus*, *L. arboreus*, *L. clymenum* L., and *Cicer arietinum* L., was the same as his observation on *Vicia Faba*.

Pisum sativum L. [Text-fig. 40, Q]. Leaves, even-pinnate; leaflets, 2-3 paired, and a few pairs of tendrils. The condition in the petiolar base is nearly the same as that of *Vicia unijuga*, but, in the slender part of the petiole, many bundles are arranged on a circle (Text-fig. 40, Q). Among those bundles, five are predominant in size (m , l_1 , l'_1 , l_2 , l'_2) and are provided with a few small bundles between them. The vascular supply to the leaflets takes place normally.

[10] PHASEOLEÆ.

Rhynchosia volubilis LOUR. [Text-fig. 41, A-E]. Leaves, pinnately trifoliate. Trilacunar. The whole vascular system is the same as the case of *Desmodium racemosum*, that is, at the pulvinus three foliar traces are fused into a continuous ring (Text-fig. 41, A), which is then divided into five main bundles and a pair of ridge bundles at the transitional region between the pulvinus and the slender part of the petiole (Text-fig. 41, B); such a condition is retained throughout the whole slender part of the petiole (Text-fig. 41, C: middle of the petiole). At the nodule three main bundles and a pair of ridge bundles in the internodule are formed as in the case of *Desmodium* (Text-

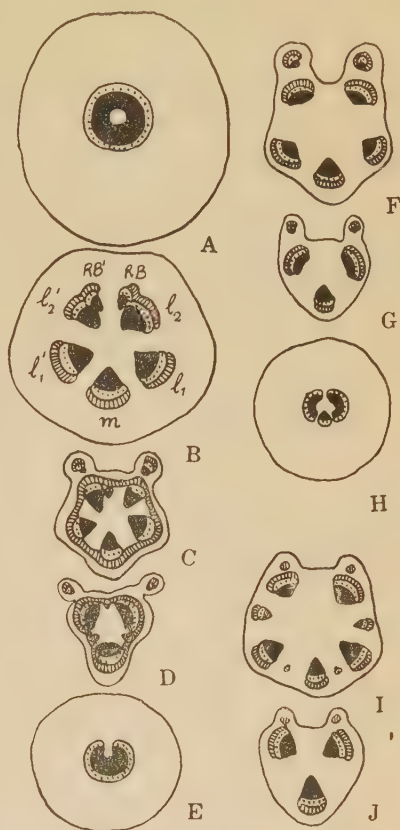
fig. 41, D); the bundle for the leaflet represents an arc in transverse section (Text-fig. 41, E).

Amphicarpæa japonica B. FEDTSCH. [Text-fig. 41, F-H]. The vascular system is the same as that of *Rhynchosia volubilis* (Text-fig. 41, F: middle of the petiole; Text-fig. 41, G: middle of the internode). The bundle for the leaflet is composed of a small median bundle and a pair of large lateral ones (Text-fig. 41, H).

Dumasia truncata SIEB. et ZUCC. [Text-fig. 41, I and J; and Pl. VI, fig. 16]. The vascular system is nearly the same as that of *Rhynchosia volubilis*. Rather prominent ridges are seen along the whole slender part of the petiole and internode, containing only mechanical elements instead of the ordinary ridge bundles (Text-fig. 41, I; and Pl. VI, fig. 16: middle of the petiole; Text-fig. 41, J: middle of the internode). The fascicles for the stipels issue from the vascular complex which is formed on the ventral side of the nodule.

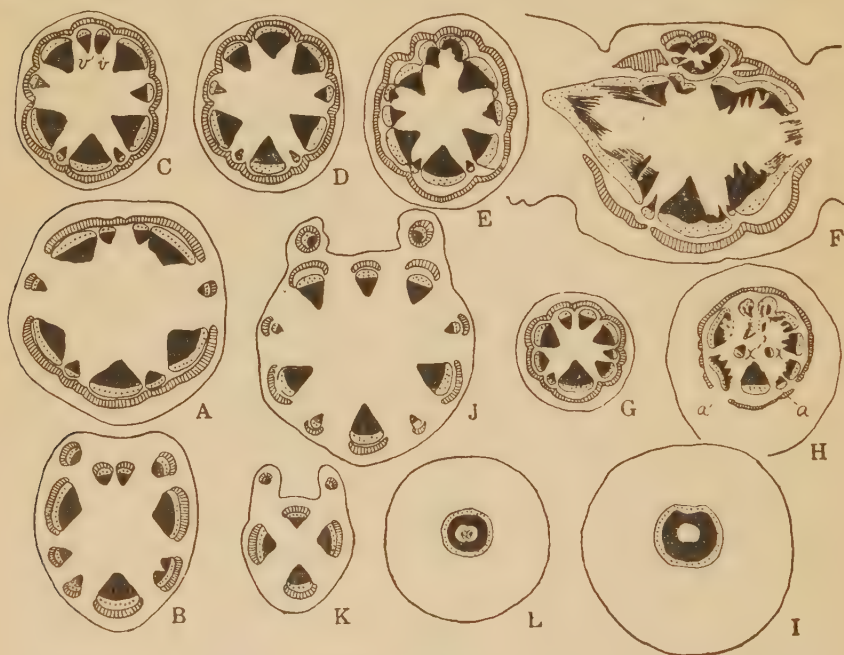
Mucuna Toyoshimai NAKAI [Text-fig. 42, A and B]. The vascular system is also nearly the same as that of *Rhynchosia volubilis*, but the ridge bundles are altogether wanting in the slender part of the petiole (Text-fig. 42, A: middle of the petiole), though they appear in the internode (Text-fig. 42, B: middle of the internode).

Mucuna ferruginea MATSUM. [Text-fig. 42, C-I; and Pl. VI, fig. 17]. Leaves, pinnately trifoliolate. The condition in the basal part of the petiole is the same as in the former examples. In the slender part of the petiole, five main bundles are formed together with a pair of rather large ventral bundles (*v* and



Text-fig. 41. *Rhynchosia volubilis* (A-E, $\times 12$): A and B, pet. bas.; C, pet. mid.; D, mid. of internod.; E, mid. of petiolule of the terminal leaflet. *Amphicarpæa japonica* (F-H, $\times 12$): F, pet. mid.; G, mid. of internod.; H, mid. of petiolule of the terminal leaflet. *Dumasia truncata* (I and J, $\times 10$): I, pet. mid.; J, mid. of internod.

v') which in other examples are either rather small (e. g. *Mucuna Toyoshimai*) or altogether absent (e. g. *Amphicarpæa japonica*) (Text-fig. 42, C); sometimes, through the fusion of bundles v and v' six large bundles are seen which are nearly equal in their size (Text-fig. 42, D; and Pl. VI, fig. 17). Just below the nodule, the bundles on the ventral side issue out of the vascular circle to form an incomplete ringlet (Text-fig. 42, E and F); this ringlet then forms the vascular complex, a part of which is supplied to the bundles for each lateral leaflet caused from the lateral bundles in the ordinary manner (Text-fig. 42, F).



Text-fig. 42. *Mucuna Toyoshimai* (A and B, $\times 20$): A, pet. mid.; B, mid. of internod. *Mucuna ferruginea* (C-I, $\times 12$): C and D, pet. mid.; E and F, nod.; G, mid. of internod.; H, top of internod.; I, mid. of petiolule of the terminal leaflet. *Apios Fortunei* (J-L, $\times 25$): J, pet. mid.; K, mid. of internod.; L, mid. of petiolule of the terminal leaflet.

Though these conditions are nothing but a case stated in *Lespedeza tomentosa*, *Desmodium racemosum*, etc., the topographical disposition of the bundles in this region remind us of those in *Cæsalpinia* sps. There are three main bundles and no ridge bundles in the internodule (Text-fig. 42, G: middle of the internodule). At the base of the petiolule of the terminal leaflet, a small bundle is segmented, as the medullary bundle, from each small petiolar bundle immediately next to the median one, and at the same time, the bundles situated

on the ventral side show some irregularities (Text-fig. 42, H: x and x' are derived from a and a'). Such medullary bundles, however, are soon inserted into the ventral portion of the vascular circle, and there forms a continuous ring through the whole length of the short petiolule (Text-fig. 42, I: middle of the petiolule). The same condition is seen in each petiolule of the lateral leaflets.

Apios Fortunei MAXIM. [Text-fig. 42, J-L]. Leaves, odd-pinnate; leaflets, 1-2 paired. The vascular system in the case of pinnately trifoliolate leaves is nearly the same as that of *Rhynchosia volubilis*. In the case in which there are two pairs of leaflets, the disposition of the bundles in the slender part of the petiole (Text-fig. 42, J) and the first internodule, and that in the second internodule (Text-fig. 42, K), are each the same as those in the petiole and internodule of *Rhynchosia volubilis*. In this species, a pair of minute medullary bundles with the same origin as in *Mucuna ferruginea* are seen throughout the whole length of the petiolule of each leaflet (Text-fig. 42, L: middle of the petiolule of a leaflet).

Canavalia ensiformis DC. [Text-fig. 43, A and B]. Leaves, pinnately trifoliolate. The condition in the basal part of the petiole and the nodule are the same as those of *Rhynchosia volubilis*. In the slender part of the petiole, there are a pair of ridge bundles and a continuous ring in which the portions corresponding to the main five bundles are distinguished as in many other examples, by the presence of the protoxylem groups, and the crowded situation of the conductive elements; between these portions the secondary elements produced by the interfascicular cambium are inserted (Text-fig. 43, B). But in the transitional region between the pulvinus and the slender part of the petiole, the five bundles are clearly observed (Text-fig. 43, A). In the internodule, a pair of ridge bundles are also seen together with a continuous ring in which the main protoxylem groups are three instead of five. The bundle for the petiolule represents an open arc in transverse section.

In *Canavalia lineata* DC., with the same foliar type, five foliar traces come out of five distinct gaps in the stem, and these strands are fused into a continuous ring as in the case of some species of *Desmodium*. This continuous ring is divided into five bundles at the transitional region, but among these bundles, the lateral bundles near the median bundle are soon divided into a few smaller ones. In the slender part of the petiole, these bundles form, together with the secondary interfascicular elements, a continuous ring (Text-fig. 43, C). The other conditions are the same as those of the former example.

Clitoria ternata L. [Text-fig. 43, D]. Leaves pinnately trifoliolate. Trilacunar. The condition in the basal part of the petiole is exactly the same as that of *Rhynchosia volubilis*. In the slender part of the petiole and the internodule, however, there are three main bundles (Text-fig. 43, D: middle of the petiole) in which a pair of large lateral bundles correspond to two pairs of lateral bundles in the preceding examples.



Text-fig. 43. *Canavalia ensiformis* (A and B, $\times 15$): A, pet. bas.; B, pet. mid. *Canavalia lineata* (C, $\times 12$): pet. mid. *Clitoria ternata* (D, $\times 25$): pet. mid. *Dolichos Lablab* (E-N; E-M, $\times 15$; N, $\times 50$): E, mid. of pulv.; F, pet. mid.; G-K, nod.; L, mid. of internod.; M and N, mid. of petiolule of the terminal leaflet. *Glycine Soja* (O, $\times 12$): pet. mid.

Dolichos Lablab L.¹⁾ [Text-fig. 43, E-N]. Leaves, pinnately trifoliolate. Five foliar traces come out of five distinct gaps in the stem. The vascular

1) ACQUA (1887) states that *Phaseolus vulgaris*, *Dolichos giganteus*, *Pueraria Thunbergiana* commonly have five foliar traces, and that the vascular system in the petiole of these species are the same in many respects.

system in the basal part of the petiole, the pulvinus, the slender part of the petiole, and the internode is the same as in *Rhynchosia volubilis* (Text-fig. 43, E: middle of the pulvinus; F: middle of the petiole; H: middle of the internode). The condition in the nodule, however, is much more complicated than in former examples; here, there are seen not only the vascular complex on the ventral side of the nodule (Text-fig. 43, G-K), but when the lateral bundles in the internode are formed by the fusion of the remaining part of two pairs of lateral bundles (l_1 , l_2 , and l'_1 , l'_2 in Text-fig. 43, G) there also form a pair of complicated entanglements of the vascular elements at both lateral sides of the nodule (Text-fig. 43, H and I). Moreover, the median petiolar bundle reinforces the lateral bundle, and, at the same time, a small part of the median bundle is added to the vascular supply to each lateral leaflet (Text-fig. 43, G and H). A pair of minute medullary bundles are seen in the concavity of the arc throughout the whole length of the petiolule of each leaflet (Text-fig. 43, M and N).

Glycine Soja BENTH. [Text-fig. 43, O]. Though the foliar traces come out from three gaps, the rest of the vascular system shows a similarity to that of *Dolichos Lablab* (Text-fig. 43, O: middle of the petiole).

Erythrina crista-galli L.¹⁾ [Text-fig. 44, A-K; and Pl. V, fig. 5]. Leaves, pinnately trifoliolate. Trilacunar. At the base of the pulvinus, three foliar strands are fused into a flattened ellipse, the ventral portion of which is composed of both marginal portions of each original foliar trace (Text-fig. 44, A and B). The ventral portion of this ellipse soon becomes an irregular vascular complex, and, higher up, there again forms a continuous ring, enclosing a pair of small amphivasal medullary bundles in which the woody parts consist of relatively few conducting elements, and the phloem chiefly of parenchyma (Text-fig. 44, C and D). These medullary bundles are then divided into an indefinite number, and eventually are gradually inserted into the various portion of the outer ring (Text-fig. 44, E-I; and Pl. V, fig. 5). As soon as the insertion of these bundles is finished at the transitional region between the slender part of the petiole and pulvinus, the continuous ring divides into five main bundles (m , l_1 , l'_1 , l_2 , l'_2), a rather large one (v) being situated on the ventral

1) PETIT (1887) says that *Erythrina crista-galli*, *Glycine sinensis*, *Apios tuberosa*, and *Phaseolus multiflorus*, in which the former three belong to the trilacunar type and the latter to the pentalacunar, represent the same vascular system except for the fact that *Erythrina crista-galli* has no ridge bundles ("..... les deux faisceaux supérieurs manquent"). The medullary bundles in the pulvinus were not treated by him.

side. These figures (Text-fig. 44, E-I; and Pl. I, fig. 5) show the case in which the division of the medullary bundles are rather numerous. If the number of medullary bundles are few, they are mainly inserted into the ventral side of the continuous ring. Except for the lack of the ridge bundles and the ap-



Text-fig. 44. *Erythrina crista-galli* (A-K; A-D, $\times 12$; E-I, $\times 25$; J and K, $\times 12$): A-I, pet. bas.; J, pet. mid.; K, mid. of internod. *Erythrina indica* (L and M, $\times 15$): L, pet. bas.; M, pet. mid. (Cav., cavity). *Glycine ussuriensis* (N, $\times 25$): pet. mid. *Phaseolus multiflorus* (O and P, $\times 7$): O, mid. of pulv.; P, pet. mid. *Pueraria Thunbergiana* (Q-V, $\times 7$): Q-U, pet. bas.; V, pet. mid. *Phaseolus angularis* (W, $\times 7$): pet. mid. *Vigna sinensis* (X, $\times 7$): pet. mid.

pearance of the medullary bundles in the petiolule of each leaflet, the further condition is the same as that of *Rhynchosia volubilis* (Text-fig. 44, J: middle of the petiole; K: middle of the internodule).

In *Erythrina indica* LAM., with the similar foliar type nearly the same vascular system is found (Text-fig. 44, M: middle of the petiole), but in this species, though the vascular complex is seen at the base of the pulvinus (Text-fig. 44, L), there are no medullary bundles in the large part of the pulvinus.

Glycine ussuriensis REG. et MAACK [Text-fig. 44, N]. Though there are three foliar traces, the vascular system in the basal part of the petiole and pulvinus is the same as that of *Dolichos Lablab*. But the medullary bundle in the pulvinus is single, and is inserted into the ventral portion of the continuous ring at the transitional region between the pulvinus and the slender part of the petiole. The other conditions are the same as in the case of *Rhynchosia volubilis* (Text-fig. 44, N: middle of the petiole).

Pueraria Thunbergiana BENTH. [Text-fig. 44, Q-V; Text-fig. 45; and Pl. VIII, fig. 50]. Leaves, pinnately trifoliate. Five foliar traces emerge from five distinct gaps. The stipule is composed of two parts, the upper and lower lobes, as has already been described in *Aeschynomene indica* (Hedysareæ) (Text-fig. 45, A; and Pl. VIII, fig. 50: stipule attaches to the stem with the oval region surrounded by broken line in Text-fig. 45). Many fascicles for the upper lobe branch out successively from the lateral foliar trace, which comes from the gap situated on the vascular cylinder of the stem, far from the median one. The fascicles for the lower lobe branch out from a branch of the lateral foliar trace. In Text-fig. 45, there are seen a part of the foliar trace (L) and the branch, both of which form a continuous circuit. The condition in the basal part of the pulvinus is the same as in the case of *Erythrina crista-galli* (Text-fig. 44, Q-T), but in the large part of the pulvinus there are no medullary bundles (Text-fig. 44, U).¹⁾ The vascular system in the slender part of the petiole (Text-fig. 44, V), the nodule, and the internodule is the



Text-fig. 45. Two-lobed stipule of *Pueraria Thunbergiana* ($\times 4$).

1) According to AVETTA (1884) in *Pueraria Thunbergiana* BENTH., there are many medullary bundles throughout the whole length of the pulvinus.

same as in *Rhynchosia volubilis*. In the basal part of the petiolule of each leaflet, a pair of minute medullary bundles are seen.

Phaseolus angularis W. F. WIGHT (*Dolichos angularis* WILLD.) [Text-fig. 44, W]. The stipule is the same as that of *Pueraria Thunbergiana*. The other conditions are the same as those of *Dolichos Lablab* (Text-fig. 44, W: middle of the petiole), but there are no medullary bundles in the petiolule of the leaflet.

The foliar traces in **Phaseolus multiflorus** WILLD. are five in number and there appears, through the pulvinus, a single medullary bundle (Text-fig. 44, O) which inserts itself into the ventral portion of the outer ring at the transitional region between the pulvinus and the slender part of the petiole; but the other conditions are nearly the same as those of *Rhynchosia volubilis*. The lateral bundles l_2 and l'_2 are rather large and are often respectively divided or segmented into two (Text-fig. 44, P: middle of the petiole).

Vigna sinensis ENDL. [Text-fig. 44, X]. Here also the two-lobed stipules are seen, while the number of the foliar traces, and the condition in the slender part of the petiole (Text-fig. 44, X), and the internodule is the same as those of *Dolichos Lablab*. The medullary bundles are seen in the pulvinus, but they are wanting in the petiolule.

The vascular system of **Vigna sinensis** ENDL. var. **Catiang** NAKAI is entirely the same as that of *V. sinensis* ENDL.

Though the numerous species we have mentioned above fundamentally belong to the types which are closely related to one another, yet there are various delicate differences appearing in various combinations; the following table is given in order to show these differences and combinations.

Table I. Diagnostic representation of the characters of the foliar organs of tribe *Phaseoleæ*.

Name of species	Lt	st	Lg	B	PI		rb		n	pm
					p	i	p	i		
<i>Clitoria ternata</i>	0-pin (1-3)		3	c	3s	3s	+	+	Rh	—
<i>Amphicarpæa japonica</i>	3-pin		3	c	5s	3s	+	+	Rh	—
<i>Dumasia truncata</i>	3-pin		3	c	5s	3s	(±)	(±)	Rh	—
<i>Glycine Soja</i>	3-pin		3	c	5s	3s	+	+	Do	+

<i>G. ussuriensis</i>	3-pin		3	m	5s	3s	+	+	Rh	—
<i>Erythrina crista-galli</i>	3-pin		3	m	5s	3s	—	—	Rh	+
<i>E. indica</i>	3-pin		3	bm	5s	3s	—	—	Rh	+
<i>Apios Fortunei</i>	0-pin (1-3)		3	c	5s	3s	+	+	Rh	+
<i>Mucuna Toyoshimai</i>	3-pin		3	c	5s	3s	—	+	Rh	—
<i>M. ferruginea</i>	3-pin		3	c	5s	3s	—	—	Rh	+
<i>Pueraria Thunbergiana</i>	3-pin	T	5	bm	5s	3s	+	+	Rh	+
<i>Canavalia ensiformis</i>	3-pin		3	c	5c	3c	+	+	Rh	—
<i>C. lineata</i>	3-pin		5	c	5c	3c	+	+	Rh	—
<i>Rhynchosia volubilis</i>	3-pin		3	c	5s	3s	+	+	Rh	—
<i>Phaseolus multiflorus</i>	3-pin		5	m	5s	3s	+	+	Rh	—
<i>P. angularis</i>	3-pin	T	5	c	5s	3s	+	+	Do	—
<i>Vigna sinensis</i>	3-pin	T	5	m	5s	3s	+	+	Do	—
<i>V. sinensis</i> var. <i>Catiang</i>	3-pin	T	5	m	5s	3s	+	+	Do	—
<i>Dolichos Lablab</i>	3-pin		5	c	5s	3s	+	+	Do	+

Lt. Type of the leaves. 3-pin..... pinnately trifoliolate leaves; Odd-pin..... odd-pinnate leaves; numerals within the brackets show the number of pairs of lateral leaflets.

st. Stipules. T..... two-lobed stipule.

Lg. Number of the foliar gaps.

B. Condition in the basal part of the petiole and pulvinus. c..... foliar strands are fused into a continuous ring without medullary bundles at the pulvinus, after passing through the same processes as seen in *Desmodium*; bm..... at the base of pulvinus, medullary vascular complex is found, but in the greater portion of pulvinus, there is a continuous ring without medullary bundles; m..... having the vascular complex at the base of the pulvinus, and a continuous ring with medullary bundles throughout the whole length of the pulvinus.

PI. Conditions in the slender part of the petiole (p) and internodule (i) (in odd-pinnate leaf, the condition in the uppermost internodule). 5s..... separated bundles in which five main; 3s..... separated bundles in which three main; 5c..... continuous ring in which the portions corresponding to five main are distinguishable; 3c..... continuous ring in which three main are distinguishable.

rb. The ridge bundles in the slender part of the petiole (p) and internodes (i) +..... present; —..... absent.

n. The condition in the nodule. Rh..... type of *Rhynchosia*; Do..... type of *Dolichos Lablab*.

pm. The medullary bundles in the base of the petiolule of leaflet. +..... present; —..... absent.

PART II. SUMMARIZED INFORMATION.

In the preceding part, we have described the vascular system in the foliar organ in each species of the *Leguminosæ*, with special reference to the petiole, the nodule and the internodule. We have found that there are many varying types, ranging from the simplest to the most complicated. Moreover between these two extremes, there are many intermediate forms, which may explain the relationship between the different kinds of the vascular systems. In the present part, these various forms will be contrasted and compared, and thus a general conception of the vascular structure of this family will be given.

In giving the summarized information and comparing the relations between these various types, it is preferable for ease of description, to divide the vascular system in the foliar organ into a few regions—such as the node, the basal and slender parts of the petiole, the nodules, and the internodes. As is already accepted by previous investigators, the number of the gaps of the stem caused by the insertion of one leaf shows approximate similarity among the species which belong to a closely allied systematic group, the trilacunar type being the most prevalent condition in this family. However, the appearance of the various types in one and the same family, though such an appearance is rather rare, is worth noticing. In the basal and slender parts of the petiole, we see some characteristic features of the vascular system which may be independent of the external-morphological characters, especially of the leaf-types such as the palmate or pinnate form; while in the regions above the petiolar top, we find some important suggestions in regard to the relationship between the various leaf-types. The conditions in these various regions will be stated somewhat precisely in the following pages.

A. The Nodal Region.

It will be appropriate to begin with the *node* where the leaf attaches itself to the stem. SINNOT (1914) states in his phylogenetical work, that the leaf of leguminous plants is almost always supplied with three foliar traces each coming out of each gap in the cylinder of the stem; such a type is called the *trilacunar type*. Occasionally, however, a case of five gaps is found. ACQUA

(1887) also, who attaches much importance to the number of foliar traces¹⁾ when he divides the types of the vascular systems in the petioles of dicotyledonous plants, observes the trilacunar type to be the most usual in species of this family, cases of one or five gaps²⁾ being only occasional. In the present study also besides the trilacunar type a few unilacunar and multilacunar types were observed.

‡ **Unilacunar type.** The case of a single gap is observable only in a few related species of *Genistæ* namely, *Genista pilosa* (Text-fig. 46, A), *G. anglica* (Text-fig. 27, G), *G. germanica* (Text-fig. 27, D), *Ulex europæus* (Text-fig. 27, H) and *Cytisus Scoparius* (Text-fig. 27, I; and Pl. V, fig. 2).

‡ **Trilacunar type.** All species among the *Mimosoideæ* show the trilacunar type (Text-fig. 46, fig. B: *Albizia Julibrissin*) and nearly all of the *Cæsalpinioidæ* and *Papilionatæ* as well.

‡ **Multilacunar type.** In some cases, however, we meet with the multilacunar type among *Cæsalpinioidæ* and *Papilionatæ*. Some species show the multilacunar node only in the vigorous leaves, while a few of the foliar traces are often very feeble, the foliar traces occasionally being even in number, owing to the lack of one of these feeble foliar traces.

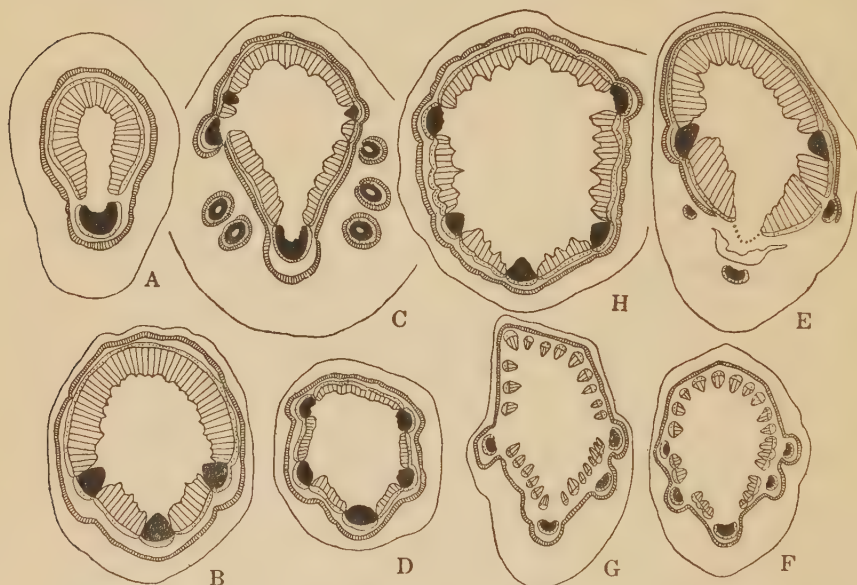
Among *Cæsalpinioidæ* the multilacunar type is found only in a few genera. In *Erythrophleum guineense* there are usually nine foliar traces each coming out from its own gap (Text-fig. 46, C), the outermost pair of which are feeble; indeed, there is often the case with eight or seven gaps owing to the absence of one or both of this outermost pair. *Cæsalpinia Sappan* and *C. Bonducella* show respectively five (Text-fig. 46, D) and seven gaps (Pl. V, fig. 1). The multilacunar node seems to occur not only in the above-mentioned genera, but I have also observed a case in which five bundles are arranged in the leaf-scar of *Schizolobium excelsum* Vog., though in the scars situated on the lower levels of the same shoot, there are three bundles.

Among the *Papilionatæ* this nodal type appears among the genera in different natural systematic groups. In *Cladrastis lutea*, there are five foliar traces that issue from distinct gaps, a pair of which, next to the median one are very feeble (Text-fig. 46, E). In *Desmodium racemosum* and *D. podocarpum* var. *indicum* a few of the first formed leaves are nearly always supplied

1) In his work, the number of foliar traces is taken as one of the characteristics. But in this family, the number of foliar traces is nearly always the same as the number of gaps.

2) He reports the case of a unilacunar type only in *Ulex europæus*, and a case of five gaps, in *Pueraria Thunbergiana* BENTH., *Phaseolus vulgaris* L., and *Dolichos giganteus* WILLD.

with three traces from three gaps, but in the ordinary vigorous leaves, the traces often start from four or five distinct gaps (Text-fig. 46, F and G). The position of the gaps which is situated near to the median is almost definite, but in some cases it is situated very close to the median gap, and in another, near to the lateral gap. Also in *Pterocarpus indicus*, though in most cases trilacunar, we occasionally find a case of four gaps. As a contrast to the above mentioned species in which the pair of gaps next to the median one has an incomplete constancy, there are always found five gaps in species, such



Text-fig. 46. A ($\times 20$): *Genista pilosa*. B ($\times 8$): *Albizia Julibrissin*. C ($\times 8$): *Erythrophleum guineense*. D ($\times 8$): *Cæsalpinia Sappan*. E ($\times 6$): *Cladrastis lutea*. F and G ($\times 8$): *Desmodium racemosum*. H ($\times 5$): *Pueraria Thunbergiana*. Explanations in text.

as *Desmodium caudatum*, *D. Oldhamii*, *Canavalia lineata*, *Dolichos Lablab*, *Phaseolus multiflorus*, *Ph. angularis*, *Vigna sinensis*, *V. sinensis* var. *Catiang*, and *Pueraria Thunbergiana*¹⁾ (Text-fig. 46, H).

‡ **Number of the foliar traces derived from a gap.** In nearly all cases, only one bundle starts from each of the gaps, but in a few cases, three or more

1) It is reported by AVETTA (1884) that in the seedling of *Pueraria Thunbergiana*, a node where the primary leaves attach themselves opposite each other represents the trilacunar type. The same fact will be observed in others belonging to this category.

bundles are derived from one gap; for example, in *Amherstia nobilis*, three traces, the median one of which is predominant in size, come out from the median gap, while from each lateral gap there issues a single trace (Text-fig. 11, A); the same type is found in *Crotalaria usaramoensis*.

§ **Separation of the foliar traces from the vascular cylinder of the stem.** Though the bundles forming the foliar traces become distinct in the vascular cylinder of the stem, in one or two nodes below their point of departure,¹⁾ the actual separation of the foliar traces from the stele of the stem occurs, in almost all cases, in the successive levels of the node; generally the outermost lateral ones separate on the lowest level, and the median one on the highest level. The lateral traces of a certain node in *Viciae*, however, separate from the stele of the stem just above a node below, and run through an internode as the cortical bundles. NÄGELI and some others studied this condition precisely.

B. The basal sheathing, the cavity for the intra-petiolar buds, stipule, and the distribution of the vascular system in these parts.

§ **Stipule and stipular trace.** As a characteristic feature of the leguminous leaves, the stipules are almost always found persisting, often throughout the life. In general, they are of a small lanceolate shape, and the trace for this organ is mostly single or double, and composed of scanty conducting elements. The stipules of *Cercis canadensis* and *Cæsalpinia Sappan*²⁾ are rather large, but the traces are less in number and they fall down early. Large leaf-like stipules are found in *Medicago denticulata*, *Lotus corniculatus* var. *japonicus*, and many species of *Viciae*, in some of which they are supplied by several traces that issue successively from the lateral foliar trace. The membranous stipules of some species of *Trifolieæ*, combining into a well-developed leaf-base, and often embracing the stem, show an eminent feature. In *Saraca indica* and *Trifolium repens* (Text-fig. 28, A), the stipules are fused at the axil. Spiny stipules are found in *Pithecolobium dulce*, *Acacia sphærocephala*, *Robinia pseud-acacia*, and *Caragana Chamlagu*, and others. *Acacia sphærocephala* is one of the ant acacias with vigorous spiny stipules and the traces for this organ are numerous (Text-fig. 5, F). One of the most interesting stipules is found in

1) For example, according to WINTER (1932), in *Medicago sativa*, the median foliar trace becomes a definite bundle two nodes below, and the lateral ones, one node below their point of departure.

2) The stipules protect the young buds.

Cæsalpinia Bonducella; they consist of several leaflet-like segments (Text-fig. 19, A and B) and the trace for such a stipule is supplied as a single bundle which soon divides into two main branches. The stipule of some species of *Hedysareæ*, e. g. *Aeschynomene indica* (Text-fig. 36, A), many species of *Zornia* as mentioned by MALME (1931), and some species of *Phaseoleæ*, e. g. *Pueraria Thunbergiana*, *Phaseolus angularis*, *Vigna sinensis*, etc., is composed of upper and lower lobes, the latter especially *Pueraria Thunbergiana*, showing a peculiar character in its vascular supply as was stated in the preceding description (Text-fig. 45; and Pl. IV, fig. 50).

In spite of various external-morphological features, the traces are always supplied from a lateral foliar trace situated far from the median one, independent of the number of traces for the stipule. The departing point of the traces from a foliar trace may be of either one of the following two types. (a) When the foliar trace takes a form of an open arc or a bar in transverse section, the traces for a stipule are derived, in many cases, from the outer end, e. g. *Crotalaria sessiliflorus*, *Lupinus hirsutus* (Text-fig. 26, A), *Medicago denticulata* (Text-fig. 29, J), *Lotus corniculatus* var. *japonicus* (Text-fig. 30, A), *Astragalus reflexistipulus*, *Vicia nipponica* var. *typica* (Text-fig. 38, G), etc. (b) On the other hand, when the foliar trace takes a form of a deeply-curved arc or a ringlet, the traces usually issue from a portion more or less apart from the outer margin of the foliar trace, or, from the corresponding portion in the case of a ringlet, e. g. *Albizia Julibrissin* (Text-fig. 1, A), *Acacia sphærocephala*, *Styphnolobium japonicum* (Text-fig. 21, A), *Millettia reticulata*, *Pterocarpus indicus*, *Erythrina crista-galli*, etc.

‡ **Basal sheathing and the cavity for the intra-petiolar buds.** In some species, the leaf-base is characterized by possessing a more or less well-developed sheath, and it is confined only among the herbaceous species such as *Trifolium*, *Medicago*, *Lupinus*, and *Arachis*, etc. In some cases, it takes an open form which embraces the stem partially or completely as in *Trifolium pratense*, *Medicago sativa*, *Arachis hypogæa* (Text-fig. 36, F), etc.; in others, it is closed to form a tubular sheath, e. g. *Trifolium repens* (Text-fig. 28, A), *Tr. Lupinastar* (Text-fig. 28, E), etc. In any case, the foliar strands are situated separately, and their fusion or connection is never found in this region.

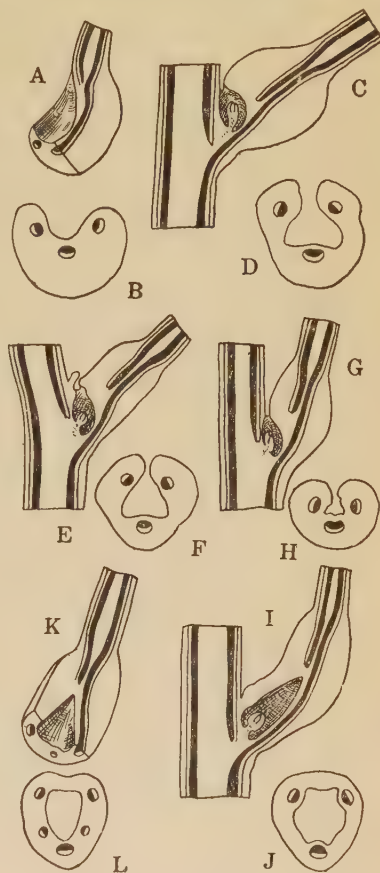
In some species of *Sophoreæ* and *Galegeæ*, a shallow or deep cavity is found involving a certain number of intra-petiolar buds.¹⁾ In many species, for

1) The presence of this cavity was pointed out by VAN TIEGHEM (1905) in some species under the name of "la chambre gemmaire" or "poche gemmaire".

example in *Maackia amurensis* var. *Buergeri*, the bud is situated in the shallow cavity engraved on the ventral side of the base of the pulvinus, but yet the bud itself is exposed to the outside (Text-fig. 47, A and B). In some species, however, such a cavity is buried between the stem and the petiolar base and, at the same time, it intrudes slightly into the petiolar base. In such a case, generally, this cavity still shows a more or less narrow opening; *Styphnolobium japonicum* (Text-fig. 47, C and D), *Robinia pseudacacia* (Text-fig. 47, E and F), *Robinia hispida* (Text-fig. 47, G and H), etc., are representatives of this type. Moreover, in some others, this cavity is completely enclosed to form a more or less deep conical room without an opening; *Platysprion platycarpum* (Text-fig. 47, I and J) and *Cladrastis lutea* (Text-fig. 47, K and L), are characterized by this feature. In any case, the fusion of the foliar traces are performed at the level above this cavity. From this point, this condition may be considered as a special case in which the petiolar base embraces the axillary bud, and as an intimately allied organ with the basal sheathing which embraces the stem.¹⁾

C. Vascular system in the petiolar base and the slender part of the petiole.

SINNOT and BAILEY (1915) are convinced that the most primitive type of the vascular system in the petiole is that in which there are three foliar traces coming out from their own gaps and running separately through the whole course



Text-fig. 47. A and B ($\times 3$): *Maackia amurensis* var. *Buergeri*. C and D ($\times 3$): *Styphnolobium japonicum*. E and F ($\times 3$): *Robinia pseudacacia*. G and H ($\times 4$): *Robinia hispida*. I and J ($\times 5$), *Platysprion platycarpum*. K and L ($\times 3$): *Cladrastis lutea*. Explanations in text.

1) GRAVIS (1930) mentioned that the basal sheathing in *Genista radiata* contained many axillary buds to form the "poche gemmaire".

of the petiole. But there are no such examples in the leguminous leaves so far as my present observations are concerned. In all cases, except that of the unilacunar type, three or more foliar traces are fused or connected with each other at the basal part of the petiole. Consequently, the petiolar base is one of the most important regions in the vascular course of the foliar organ of this family.

That condition in which the foliar traces are connected by their branches is widely prevalent among the herbaceous species lacking the pulvinus at the petiolar base, while the other condition in which the foliar traces are fused into a ring or an arc is nearly always found in species with a more or less conspicuous pulvinus, regardless whether they are woody, frutescent, or herbaceous. In considering and comparing the vascular systems in the basal and slender parts of the petiole, it is more convenient to begin with the consideration of the former; for, though they are relatively few, yet in them the derivation of the petiolar bundles from the foliar traces can easily be observed. Thus, we can understand the true significance of the latter cases, in which the relation between the foliar traces and the petiolar bundles are obscured by the presence of the pulvinus where the traces are fused into a single strand.

In the following descriptions, for the purpose of avoiding complications, only a few examples are mentioned in each type, the type to which a certain species should belong being indicated by the signs I, II-A (a), II-A (b), II-B (a), which show respectively the types to be described in the lines that follow. In many species, the ridge bundles are separated from the regular arrangement of the petiolar bundles at the transitional region between the pulvinus (or petiolar base) and the slender part of the petiole. The separation of the ridge bundles and their further behaviour will be stated in subsequent pages (cf. pp. 338-342).

‡ **Type I.** This is the case with a single foliar trace; that is, a single foliar trace which represents an open arc in the transverse section issues from the stele of the stem and enters the lamina without dividing or giving off a pair of minute ridge bundles. This condition is seen only in the closely allied genera of *Genisteæ*, i. e. *Genista pilosa*, *G. germanica*, *G. anglica*, *Ulex europæus*, and *Cytisus Scoparius* (Text-fig. 27; and Pl. V, fig. 2). The topography of the main bundle in the petiole is formulated here as follows.

m (1)

‡ **Type II.** Foliar traces which keep more or less apart from one another, are, at the basal part of the petiole, connected by their branches in various

ways, by which the number of main bundles in the slender part of the petiole is determined. This type prevails widely among the herbaceous species¹⁾ without the pulvinus at the petiolar base, and is divided into several subtypes according to the mode of connection. It is convenient to deal with that case first in which three foliar traces give off five main petiolar bundles, because other cases can easily be explained in connection with some anomalous cases of this type. The explanation of the types in the following lines, is given mainly showing the case of trilacunar type.²⁾

A (a): A branch of each lateral foliar trace (L and L') and two branches from the median foliar strand (M) furnish two new petiolar bundles (l_1 and l_1'), each of which is inserted between two bundles (l_2 and m , or l_2' and m) (Text-fig. 48, A); thus, in the slender part of the petiole, there are five main bundles arranged generally on an open or a deeply curved arc, and, in usual cases, considerably separated from one another. A few small bundles may occur between each two of the five main bundles. (e.g. *Pisum sativum*. see Text-fig. 40, Q).

This type is typically represented by *Trifolium* (*Tr. repens*, Text-fig. 28, A; *Tr. pratense*) and some species of *Vicia*,³⁾ such as *Vicia unijuga* (Text-fig. 38, A; and Pl. VI, fig. 20), *V. sativa*, *V. hirsuta*, *V. tetrasperma*, etc., and the mode of arrangement of the petiolar bundles may be formulated as follows.

$$\begin{array}{ccccccc} l_2' & & l_2 & & l_2' & & l_2 \\ l_1' & l_1 & \text{or} & l_1 & & l_1 & \dots\dots\dots (2) \\ & m & & & & m & \end{array}$$

As was stated in some cases of *Vicia bifolia*, both the lateral petiolar bundles (l_1 and l_2 , or l_1' and l_2') are situated very close to each other owing to the shortness of the branches from the lateral foliar trace; their complete fusion (l_1 and l_2 or l_1' and l_2') is rarely found. The latter case is treated in the present article as another type, viz. II-C(a).

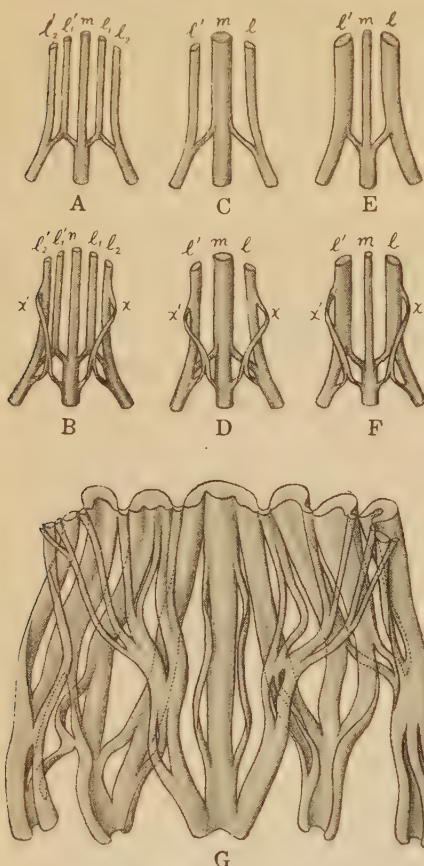
A (b): Besides the above-mentioned connection at the basal part of the petiole, a pair of small bundle (x and x' , in Text-fig. 48, B) issue from three

1) We can see only such a few examples in arborescent species (e.g. *Cæsalpinia*).

2) In fact, within the extent of the present investigation, all herbaceous examples belonging to this type represent a trilacunar type, although one can expect other examples having five or more gaps. A case of a multilacunar node is seen in the arborescent species of *Cæsalpinia*.

3) *Vicia Faba*, in the leaves having a small number of leaflets, this condition is represented.

foliar traces, which bundles in many cases occur nearly at the same level where the foliar traces are connected, and pass through the ventral portion



Text-fig. 48. Various cases of vascular system belonging to the Type II. In D, figure is drawn as shown the stele cuts open along the ventral-median line. Explanations in text.

of the basal connection (Text-fig. 48, B). Their further behaviour varies; in some species for example they are situated between l_1 and l_2 (or l_1' and l_2') (e.g. *Lathyrus vernus*, Text-fig. 40, A); in others, they are situated on the ventral portion of the arc on which the main petiolar bundles are arranged (e.g. *Vicia nipponica* var. *typica*, Text-fig. 38, G), while yet again, in others, they are fused with the lateral bundles (l_2 and l_2') (*Lathyrus Davidii*).

B (a): A branch from each lateral foliar trace is fused with the median one at the basal part of the petiole; thus, there are seen three main bundles, a large median bundle (m) and a pair of rather small lateral ones (l and l') (Text-fig. 48, C); the former of these is considered, from the condition of the basal connection, as a case in which the lateral bundles l_1 and l_1' in the preceding type A (a) or A (b) are fused with the median bundle m ; thus, the arrangement of

$$\begin{array}{c} l_2' \qquad \qquad \qquad l_2 \\ l_1' \text{---} m \text{---} l_1 \end{array} \dots \dots \dots (3)^{1)}$$

Lotus corniculatus var. *japonicus* (Text-fig. 30, B) and *Astragalus sinicus* (Text-fig. 33, G) are the representatives, and in *Lupinus luteus*, branches from the lateral foliar traces and those from the median one give temporarily a pair

1) $l'-m-l$ does not mean, that three segments corresponding to the three bundles l_1 , m , and l_1' are discerned.

of bundles but these are soon fused with the median one so as to take the arrangement formulated above (Text-fig. 25, O).

B (b): Besides the connection at the basal part of the petiole such as in *B (a)*, a pair of small bundles (x and x'), which may be a group of minute fascicles in some cases (as was mentioned in the foot-note in the description on *Astragalus reflexistipulus* (p. 287)), issue from three foliar traces in the manner stated in *A (b)* (Text-fig. 48, D). This condition is typically represented by *Astragalus reflexistipulus* (Text-fig. 33, D)¹⁾ and *A. adsurgens*. In *Lupinus hirsutus* (Text-fig. 26, A) often one and sometimes both the small bundles from the median foliar trace are wanting. The arrangement of the petiolar bundles is represented by formula (3).

C (a): At the basal part of the petiole, branches from the median foliar trace are fused with the lateral foliar traces to form a pair of large lateral petiolar bundles (l and l') and a median bundle (m) (Text-fig. 48, E); the arrangement of the petiolar bundles are thus formulated.

$$\begin{array}{ccc} l_2' & & l_2 \\ \searrow & & \swarrow \\ l_1' & m & l_1 \end{array} \dots\dots\dots (4)$$

Though this type is only found in some exceptional cases in *Vicia bifolia* and *Trifolium repens*, it has an important significance for the explanation of Type III.

C (b): Besides the connections at the basal part of the petiole in *C (a)*, a pair of small bundles (x and x') issue from three foliar traces as in the manner stated in *A (b)* or *B (b)* (Text-fig. 48, F). Within the extent of my present investigation, this type is found only in *Crotalaria sessiliflora*, in which branches from the lateral traces and those from the median one often, temporarily give a pair of bundles corresponding l_1 and l_1' in the case of *A (a)* or *A (b)*, but they are soon fused with the lateral strands, to take the arrangement of petiolar bundles shown in the formula (4).

D: At the basal part of the petiole, the foliar traces are respectively divided into a number of bundles, and, after going through a complicated mutual connecting of the bundles, they are arranged on a circle on which the bundles

1) In Text-fig. 33, D, l_1 and l_1' are feeble and cannot be considered as the main bundles, but they are only the branches of the connecting bundles at the basal part of the petiole and from their further behaviour seem to be simply a part of the median bundle.

from distinct foliar traces are arranged alternately.¹⁾ At the same time the fusion of these bundles takes place. The petiolar bundles are numerous and are situated either close together or in a dissected ring, but we can find five main bundles. So that the arrangement of the petiolar bundles may be given by the formula (2).

Such a type was observed in *Cæsalpinia japonica*, *Cæsalpinia Sappan*, and *Cæsalpinia Bonducella*. The first example is trilacunar, and the second and the third respectively have five and seven gaps, from each of which a trace is produced. Text-fig. 48, G is a diagram of a case of this type, *C. Sappan* being chosen as an example.

‡ **Type III.** In this type, the foliar traces, three or more in number, are fused at the petiolar base, into a continuous arc or ring in which, in some instances there are a few medullary bundles and in the pulvinus (nearly all species belonging to this type are provided with a more or less marked pulvinus between the leaf-base and the slender part of the petiole), the continuous ring or arc retain their continuity. At the transitional region to the slender part of the petiole, either the continuous ring or arc diverges into a certain number of petiolar bundles arranged on the periphery of the petiole; or a ring or arc in the pulvinus diverges temporarily into a certain number of petiolar bundles at the transitional region, to be again fused into a continuous ring, soon after; or the ring or arc is not separated at all but only increases its diameter.

Before subdividing the species belonging to this type, we must first consider the manner the foliar traces fuse at the petiolar base, on the stele in the pulvinus, as well as manner of transition of the petiolar stele from the pulvinus to the slender part of the petiole; we must also consider the arrangement of the petiolar bundles in the slender part of the petiole, because the relation between the foliar traces and the petiolar bundles becomes obscure, owing to the continuity within the pulvinus in which the stele becomes continuous. After dealing with these regions, I shall divide Type III into several groups

1) The alternate disposition of the petiolar bundles from distinct foliar traces is also seen in *Vicia Faba* (see, the bundles *y* and *y'* in Text-fig. 39, A), *Lupinus hirsutus* (Text-fig. 26, A), etc. But I shall put these species respectively into type A (b) and B (b), because these bundles are not so remarkable; moreover, that attaching to the types A (b) and B (b) respectively seems to be more appropriate to explain the vascular system in these species, than classifying them under the type D.

preferring the combination of the condition in the first and last regions stated above.

§§ *Fusion of the foliar traces.* Each of the foliar traces, before fusing, takes either the form of an open arc, a deeply curved arc, or a ringlet (woody part inside and phloem outside) in the transverse section, and then they are fused into a continuous ring or an arc passing through the following varying conditions.

(α) The foliar traces are fused side by side into a continuous arc (Text-fig. 49, A) or a ring (Text-fig. 49, B). *Thermopsis fabacea* (Text-fig. 23, A-C), *Baptisia australis*, *Caragana Chamlagu* (Text-fig. 33, A), and *Arachis hypogæa*¹⁾ are examples of the former case, and *Kummerowia striata* and *Cladrastis lutea*²⁾ (Text-fig. 22, N-P) of the latter. Sometimes, but rarely, three foliar traces in *Robinia hispida* are fused in this way³⁾ (Text-fig. 32, K).

(β) The foliar traces are fused into a continuous arc or ring, both extremities of the arc or ventral part of the ring being derived from the marginal portion of the original foliar traces. This condition is produced in many distinct but intimately related ways. The diagram (Text-fig. 49, C_{a-f}) shows a typical case of this condition, viz:—a pair of small bundles branch from each foliar trace—*a* and *a'* from the median bundle *M*, *b* and *c* from the lateral bundle *L*, and *b'* and *c'* from *L'* (Text-fig. 49, C_b and C_c), and the foliar traces themselves are soon fused into a continuous arc (Text-fig. 49, C_d), while the small branches *a*, *b*, *c*, and *a'*, *b'*, *c'*, are respectively fused to form a pair of bundles (*x* and *x'*) situated on the chord of the arc (Text-fig. 49, C_e); then these two (*x* and *x'*) are fused respectively to each end of the arc, to form an arc having incurved ends which are then fused so as to form a continuous ring (Text-fig. 49, C_f). This condition is typically represented by *Styphnolobium japonicum* (Text-fig. 21, B-D).

In many cases, however, the small bundles *a*, *b*, and *a'*, *b'* issue at almost the same level where the foliar traces are fused and the bundles *c* and *c'* are often wanting, thus giving rise to a continuous arc (Text-fig. 49, D) in some species, e. g. *Crotalaria usaramoensis* (Text-fig. 24, N), *Melilotus suaveolens*, *Medicago denticulata*, *Euchresta japonica*, etc., or to a continuous ring (Text-

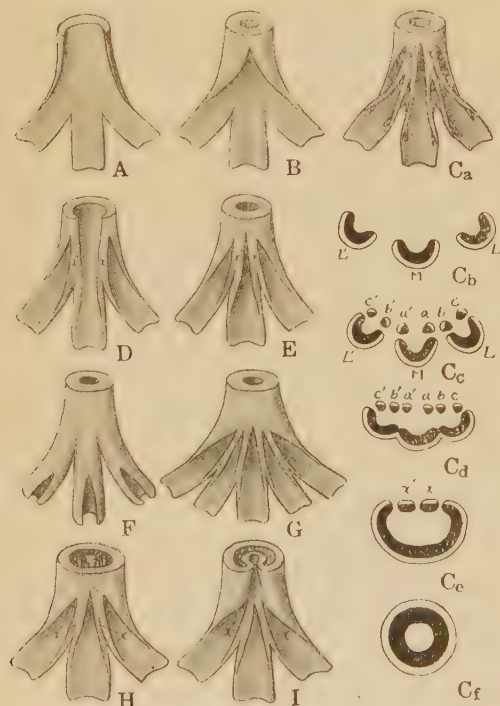
1) Three foliar traces are fused into an arc at the base of the pulvinus after they pass through the well-developed sheathing base. Possession of the sheath and the pulvinus at the same time was seen only in a few species.

2) This species represents a pentalacunar type.

3) In many cases this species show type β .

fig. 49, E) in others, e. g. *Sophora angustifolia*, *Wistaria japonica* (Text-fig. 31, A C), *Glycyrrhiza echinata*, *Amorpha fruticosa*, *Robinia pseudacacia*, *Lespedeza tomentosa* (Text-fig. 35, A), *Desmodium racemosum* (Text-fig. 35, B), *Rhynchosia volubilis*, *Apios Fortunei*, etc.

In another case, each foliar trace takes the form of a ringlet in the transverse section, and then these ringlets are fused side by side into a continuous ellipse which, in general, turns gradually into a continuous ring (Text-fig. 49, F),¹⁾



Text-fig. 49. Various cases of vascular system belonging to the Type III. Explanations in text.

In *Robinia hispida*, I found a series of these abnormalities, ranging from the typical case of β to typical α (Text-fig. 32, G-K).

(γ) The foliar traces are fused into a continuous ring passing through in the same way as in type β ; thus, the ventral portion of the continuous ring is derived from the margins of the foliar strands (x and x' in Text-fig. 49, H); but a part of the small bundles x and x' remains as a single or a few medullary bundles, which often anastomose with each other. These bundles are either soon inserted

continuous ellipse which, in general, turns gradually into a continuous ring (Text-fig. 49, F),¹⁾ e. g. *Acacia villosa* (Text-fig. 4, A and B), *Gleditschia japonica*, *Cassia Fistula*, etc. Also, in the case of the multilacunar node, the condition is the same in that the ventral portion of the ring in the pulvinus is derived from the margin of each foliar trace (Text-fig. 49, G). *Erythrophleum guineense* is the most marked example of this (Text-fig. 8, A and B).

As an abnormal case of this type one of the small bundles (x or x') is sometimes, but rarely, wanting, or in a few cases, is very feeble, e. g. *Platyosprion platycarpum* (Text-fig. 22, C).

1) *Albizzia Julibrissin*, *Pithecolobium Saman*, *Mimosa pudica*, and a few others can be considered as special cases of this condition (cf. description on each species).

into the outer continuous ring, or inserted after they have continued through almost the whole length of the pulvinus.¹⁾ This condition is quite common among the species of *Phaseoleæ*—*Erythrina crista-galli*, *Glycine ussuriensis*, *Phaseolus multiflorus*, *Vigna sinensis*, etc., providing medullary bundles throughout the whole length of the pulvinus; *Erythrina crista-galli* in particular is a marked example (Text-fig. 44, A-I and Pl. V, fig. 5); and in *Erythrina indica* (Text-fig. 44, L), *Pueraria Thunbergiana* (Text-fig. 44, Q-U), such bundles are seen only at the basal part of the pulvinus.

(δ) Though as in former examples the small bundles x and x' issue from the fusing parts of the foliar traces, the ring in the pulvinus has a more or less marked invagination on its ventral side, a part of which in some cases, is occupied by the bundle x and x' (Text-fig. 49, I), e. g. *Bauhinia alba* (Pl. V, fig. 6) *Bauhinia japonica* (Text-fig. 14, A-C), *Bauhinia acuminata*, etc.; and in some others, the invaginated portion becomes an amphivasal concentric medullary bundle which is situated within the outer ring, e. g., *Bauhinia candidans* (Text-fig. 12, J), *Tamarindus indica* (Pl. V, fig. 7), *Cercis chinensis* (Text-fig. 15, C), etc.; sometimes it takes much more complicated forms in other cases such as *Saraca indica* (Text-fig. 10, B-H), *Amherstia nobilis* (Text-fig. 11, B-E). This type is seen only in small limited and closely related genera of *Cæsalpinioidæ* as have been exemplified above.

§§ *The stele in the pulvinus and the transitional region between the pulvinus and the slender part of the petiole.* We have above considered the vascular system in the basal part of the petiole which is generally characterized by the presence of a more or less marked pulvinus. The stele in this region converges densely together in a smaller mass compared with the diameter of the pulvinus itself, even though, from the external morphological point of view it is here that the swelling of the petiole is most marked. The physiological importance of the pulvinus is repeatedly reported by many authors e. g. PREUSS (1885), HARBERLANDT (1924), SCHWENDENER (1897 and 1898), so that in the present paper, I shall limit the descriptions only to the relative size of the diameter of the stele and that of the slender part, and of the pulvinus. Comparison of the relative size of the diameter is well represented in Tab. II in which the diameter of the stele at the middle of the pulvinus is taken as 1, and that in

1) When there are single or double medullary bundles, they are usually inserted, into the ventral portion of the outer ring, but in the case of several medullary bundles, they are inserted into the various portions of the ring (cf. the description on *Erythrina crista-galli*, p. 305).

various regions is represented as follows:—P, diameter of the middle of the pulvinus; Ts, that of the stele at the transitional region between the pulvinus and the slender part of the petiole; T, that of the transitional region; ps, that of the stele at the middle of the petiole; and, p, that of the middle portion of the petiole.

Table II.

Name of plants	P	Ts	T	ps	p
<i>Albizia Julibrissin</i>	3.8	1.6	2.8	1.2	1.8
<i>Pithecolobium Saman</i>	3.3	1.5	2.3	1.2	1.7
<i>Acacia villosa</i>	3.8	1.7	3	1.3	1.7
<i>Mimosa pudica</i>	4	1.5	3	1.3	2.4
<i>Adenantha microsperma</i>	2.7	1.1	1.7	0.9	1.2
<i>Erythrophleum guineense</i>	2	0.9	1.4	0.6	0.8
<i>Saraca indica</i>	3	1.3	2.3	1	1.4
<i>Amherstia nobilis</i>	3	1.5	2.2	1.3	1.8
<i>Bauhinia japonica</i>	3.7	1.1	3	1.1	1.7
<i>Cercis chinensis</i>	3.5	1.4	2.8	1.3	2.4
<i>Cassia mimosoides</i> var. <i>nomame</i>	3	1.4	2.8	1.3	2.5
<i>Platyosprion platycarpum</i>	3.3	1.2	2.3	1.1	2
<i>Wistaria floribunda</i>	3.5	1.3	2.3	1.2	1.5
<i>Millettia taiwaniana</i>	3.3	1.5	2.7	1.2	1.7
<i>Robinia pseudacacia</i>	3	1.3	2.3	1.1	1.5
<i>Desmodium racemosum</i>	5.4	2	3.7	1.7	2.3
<i>Lespedeza tomentosa</i>	3.1	1.2	2.3	1.1	1.5
<i>Derris elliptica</i>	4	1.4	2.6	1.1	1.6
<i>Rhynchosia volubilis</i>	4.2	1.9	3.7	1.5	2.1
<i>Canavalia ensiformis</i>	3.2	1.6	2.8	1.3	1.8
<i>Pueraria Thunbergiana</i>	5	2	3.3	1.8	2.3

The relative size of the diameter of the pulvinus (Tab. II, P) varies, within the extent of my observations, from 2 to 5.4, the cases of 3–3.8 being the most prevalent. The minimum value is represented by *Erythrophleum guineense*

in which the convergence of the stele in this region is never seen and at the same time the pulvinus is ill-developed, while the maximum value is seen in *Desmodium racemosum* (and *D. podocarpum* var. *indicum*) and *Pueraria Thunbergiana* comes next. Also in the well-known example of *Mimosa pudica*, the diameter of the pulvinus is four times as large as that of its stele. As a general feature of the species having a pulvinus, though there are a few exceptions (e. g. *Erythrophloeum guineense*, etc.), the stele shows the most converged portion compared not only with the diameter of the pulvinus, but also with that of the transitional region or the slender part of the petiole.

At the transitional region between the pulvinus and the slender part of the petiole, the continuous ring or the arc in the pulvinus diverges into a certain number of petiolar bundles which in many cases are arranged on the periphery of the petiole and run separately throughout the whole length of the petiole as in many species of *Phaseoleæ*; in other cases the ring (or arc) in the pulvinus diverges temporarily into a certain number of petiolar bundles at the transitional region but soon after they again fuse into a continuous ring (*Derris elliptica*, *Millettia taiwaniana*); in others, again, the ring (or arc) is not separated, but only increases its diameter (*Cassia Fistula*, *Ormosia formosana*, etc.), so that, unlike the pulvinus region, the stele usually shows its greatest divergence at the base of the slender part of the petiole though there are also some exceptions, and according to the height of the levels, the stele again converges gradually. One can easily recognize these facts from the table.

§§ *The arrangement of the petiolar bundles in the slender part of the petiole.* The arrangement of the petiolar bundles in the petiole undergoes hardly any change, except in the upper and basal portions; in other words, the petiolar bundles are arranged in nearly the same manner throughout the whole length of the petiole, so that the transverse section through any part of the petiole shows almost a uniform condition, though there are a few exceptions (*Bauhinia*, *Cercis*, etc.). Thus, in the following explanation of the arrangement of the bundles in the slender part of the petiole, it is the conditions in the transverse section through the middle of the petiole that are mainly considered, while the conditions in the upper and lower part of the petiole are considered only in the supplement.¹⁾

The topographical dispositions of the petiolar bundles in the middle of the

1) In the case in which the petiole is extremely short as in *Amherstia nobilis*, *Mimosa myriophylla* or where there is a large nectarium as in *Acacia sphærocephala*, the mode of the arrangement of the bundles in the lowest internodule is supplementally considered,

petiole considerably vary in the different groups, while on the other hand, among the species belonging to the same group (Genera, Tribes, etc.) the conditions are almost similar to each other; there are however a few exceptions. In some species the petiolar bundles exist separately in an arc or ring form, while in others these bundles are fused into a continuous arc or ring; there are also found a series of intermediate conditions. However, so far as the comparison of the relationship among the various petiolar systems is concerned, it does not seem of much importance whether the petiolar bundles are arranged on an arc or a circle; in this article, therefore, I shall confine my explanation chiefly to that case in which the petiolar bundles are arranged on a deeply curved arc or on a circle.

The number of bundles also varies; there are three or five main bundles and other smaller ones in some instances; in some other cases however there are three or five main bundles only. Often a single bundle or a few are found on the ventral side of the circle or arc, and they are sometimes feeble; but, in some cases, in fact in all of those belonging to *Mimosoideæ* and *Cæsalpinioideæ*, the bundle on the ventral side is remarkably large and has great significance. Owing to the presence of this bundle, which was often called "the ventral bundle" in the preceding descriptions, the topography of the transverse section of the petiole shows a prominent feature. It seems that the conditions in some species of *Bauhinia* and *Cercis* are, indeed, forms intimately allied to this condition, though at a glance they often appear somewhat complicated. In fact, the intermediate conditions between the highly complicated form and that above mentioned are represented by some species of *Bauhinia*. Even in cases in which the petiolar stele represents a continuous arc or ring in the transverse section, still the portions corresponding to the main bundles and other smaller ones can be discerned by the presence of the protoxylem (or group of the protoxylems) projecting towards the pith; frequently, besides the protoxylem, such portions are discerned more clearly by the crowded situation of the vessels.

In considering the relationships between the number of the main bundles, it seems to be most convenient to begin with a fundamental type which has already been formulated in the preceding pages (viz. p. 317, Type II-A(a)) as the formula (2) which represents the case with five main bundles (m, l_1, l'_1, l_2, l'_2) situated on an arc or circle.¹⁾

1) The reason why we prefer this type as a fundamental one will be recognized when the relationship between the various cases of Type II and those of the present one, which follows has been considered. Moreover, the real meaning may be much more obviously recognized by the conditions which are found at the nodules.

On a preceding page, though I described the main bundles as being situated separately, yet the distance between each bundle and its neighbour varies; in some species, these bundles are situated widely apart from each other, while in others they are situated close together. The latter case is often described as "bundles dissected" in the preceding descriptions, though, in some cases, it is difficult to determine whether the bundles are separated or continuous. Of course, in some cases, a few small bundles are to be found between each two of these main bundles. This condition is typically represented by many species belonging to the tribe *Phaseoleæ*, namely *Rhynchosia volubilis* (Text-fig. 41, C), *Pueraria Thunbergiana* (Text-fig. 44, V), *Dumasia truncata* (Text-fig. 41, I; and Pl. VI, fig. 16), etc. Some good examples are also found in *Galegeæ* (e.g. *Robinia pseudacacia* (Text-fig. 32, F), *Indigofera incarnata* (Text-fig. 32, B; and Pl. VI, fig. 18), etc.) and *Hedysarææ* (*Aeschynomene indica* (Text-fig. 36, B), *Arachis hypogæa* (Text-fig. 36, G; and Pl. VI, fig. 21), *Desmodium racemosum* (Text-fig. 34, N; and Pl. VI, fig. 14), *Desmodium podocarpum* var. *indicum*, etc.). However, *Amorpha fruticosa* (Text-fig. 32, A) and some others (*Lespedeza Buergeri* (Text-fig. 34, J), *Lespedeza nikkoensis* (Text-fig. 34, K), etc.), often represent the other forms which are explained below.

There are several cases which can be considered as being derived through the fusion of a part of these five main bundles, as was seen in Type II-B or C.¹⁾ In some species with three main petiolar bundles, the median bundle is usually larger than each lateral bundle as was shown in the formula (3) of the Type II-B (e.g. *Caragana Chamlagu* (Text-fig. 33, B; and Pl. VII, fig. 27), *Crotalaria usaramoensis* (Text-fig. 24, O; and Pl. VI, fig. 26), *Melilotus suaveolens* (Text-fig. 29, D), *Medicago denticulata* (Text-fig. 29, K), *Medicago sativa* (Text-fig. 29, L), etc.), and some others belong to the formula (4) of the Type II-C²⁾ (*Cassia torosa* (Text-fig. 16, D), *Cassia marylandica* (Text-fig. 16, L), *Wistaria japonica* (Text-fig. 31, F), *Glycyrrhiza echinata* (Text-fig. 31, S), *Lespedeza pilosa* (Text-fig. 34, L), *Kummerowia striata* (Text-fig. 36, E), *Clitoria ternata* (Text-fig. 43, D), etc.).

1) In some cases, the derivation of that bundle is shown by the presence of segments which correspond to the original main bundles.

2) As has already been mentioned *Amorpha fruticosa*, *Lespedeza nikkoensis*, *Lespedeza Buergeri*, etc., represent this condition in some cases; on the other hand, *Lespedeza tomentosa* (Text-fig. 34, D; and Pl. VII, fig. 29), which generally represents this condition, rarely shows the condition of formula (2). Also in these species, the intermediate conditions between formulae (2) and (4) are often found, e.g. *Lespedeza Buergeri* (Pl. VI, fig. 15) and *L. nikkoensis* (Text-fig. 34, K).

There is often found a case which is intimately related to the latter, namely when two large lateral bundles become continuous to form a large arc.¹⁾ *Wistaria venusta* and *Tephrosia candida* frequently show such a condition.

That the large bundle on the ventral side, which is seen in some species of *Mimosoideæ* and *Cæsalpinioideæ* and is often referred to as the "ventral bundle" in preceding descriptions, is derived from the fusion of the lateral bundles l_2 and l'_2 can easily be shown by certain facts; for in all cases belonging to this category, the ventral bundle acts as the chief member from which a part of the vascular supply to the leaflet is issued; and in *Acacia arabica* (Text-fig. 4, E), *Acacia sphærocephala* (Text-fig. 5, H), etc., the fact that the ventral bundle is derived from a pair of bundles corresponding to l_2 and l'_2 is clearly observed.²⁾ Consequently this condition may be formulated as follows.

$$\begin{array}{ccc}
 l'_2 - l_2 & & \text{VB} \\
 l'_1 \quad \quad l_1 & \text{or, if the ventral} & l'_1 \quad \quad l_1 \dots \dots \dots (5)_a \\
 m & \text{bundle is represent-} & m \\
 & \text{ed by VB,} &
 \end{array}$$

Often the three bundles l_1 , l'_1 and m make a completely fused arc or a segmented one which is given respectively by

$$\begin{array}{ccc}
 \text{VB} & & \text{VB} \\
 l'_1 \quad \quad l_1 \dots \dots \dots (5)_b & \text{or} & l'_1 \quad \quad l_1 \dots \dots \dots (5)_c \\
 \underbrace{\quad \quad m \quad \quad} & & \underbrace{\quad \quad m \quad \quad}
 \end{array}$$

(5)_a is represented by *Albizzia Julibrissin* (Text-fig. 1, L; and Pl. VII, fig. 33), *A. Lebbek* (Text-fig. 2, E), *Pithecolobium Saman* (Text-fig. 3, C), *Mimosa pudica* (Pl. VII, fig. 31), etc., and, (5)_b and (5)_c respectively, by *Momosa myriophylla* (Text-fig. 6, C) and *Acacia arabica* (Text-fig. 4, H).

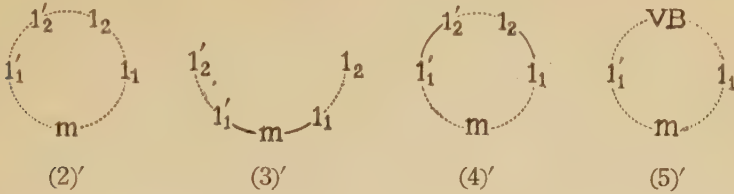
The several conditions which are represented by the formulae (1)–(5)_{a–c} hitherto-stated, are considered as fundamental types and their derivatives. The partial fusion of the main bundles in the former gives the latter. A complete continuous ring or arc in the petiole can be derived from any of these conditions and, in fact, there are many examples of the continuous ring (or arc)

1) This condition is considered as the stage showing the intermediate form between the formulae (4) and (4)' which I shall state below. This condition may be given by

$$\begin{array}{ccc}
 l'_2 \dots l_2 \\
 l'_1 \quad \quad l_1 \\
 m
 \end{array}$$

2) Also in the cases which are represented by the formulae (1)–(4), the bundles l_2 and l'_2 or the segments corresponding to these bundles tend to fuse into a large bundle at the levels of the vicinity of the node.

being derived from several distinct conditions, which according to my present observation, may be represented by the following formulae.



Styphnolobium japonicum (Text-fig. 21, H), *Ormosia formosana* (Pl. VI, fig. 23), *Platysprion platycarpum* (Text-fig. 22, G), *Indigofera Kirilowii* (Text-fig. 32, C), *Robinia hispida* (Text-fig. 32, L), *Euchresta japonica* (Text-fig. 37, C; and Pl. VI, fig. 22), *Pongamia glabra* (Text-fig. 37, E), *Canavalia lineata* (Text-fig. 43, B), etc., are examples of the formula (2)': *Thermopsis fabacea* (Text-fig. 23, D; and Pl. VII, fig. 28), *Baptisia australis* (Text-fig. 23, H), etc., are those of (3)': the case of (4)' is represented by *Millettia reticulata* (Text-fig. 31, Q), *Indigofera Dosua* (Text-fig. 32, E), etc.: and the last case (5)' is seen in *Adenathera microsperma* (Text-fig. 7, F), *Ceratonia Siliqua* (Text-fig. 16, N), *Hæmatoxylon campechianum* (Text-fig. 20, C), *Poinciana regia* (Text-fig. 20, D), *Gleditschia japonica* (Text-fig. 20, A and B).

Now that it must be understood that the description "continuous ring or arc" mentioned briefly in the preceding paragraph is to be treated in some distinct conditions. It is now convenient to turn our attention again to the constitution of the continuous ring (or arc) and the relations between the other conditions in which the bundles are disposed more or less separately. As has already been stated, even when the petiolar stele represents a continuous ring or arc, still the portions corresponding to the main bundles and other smaller ones inset between the former, are discerned by the presence of the protoxylem or groups of the protoxylem projecting towards the pith; frequently, also besides the protoxylem, such portions are discerned still more clearly by the crowded disposition of the vessels. In other words, in the course of the development of the petiolar bundles, the primary wood was at first disposed separately; the activity of the intrafascicular cambium then gradually stretches between the bundles and thus, the continuity of the bundles is accomplished. The ceasing of the cambial activity just after the bundles come in contact with each other, results in a circle with dissected bundles; such a condition often makes it difficult to discern whether the circle is continuous or separated. The definite condition of a continuous ring is brought about by the further addition of

secondary elements. In such cases the segments, if any, corresponding to the main bundles are easily discerned.¹⁾

In some instances, though groups of the protoxylem are situated close to or are widely separated from each other, the development of secondary elements in the above-mentioned manner brings about the continuity in an earlier stage. In such cases the division of the segments corresponding to the main bundles is often difficult to distinguish (e.g. *Ormosia formosana* Pl. VI, fig. 23, etc.), and they are discerned only by a close examination.²⁾

Moreover, in some other examples, the protoxylem or the groups of protoxylems are somewhat separated and the gaps or intervals of these primary strands are perpetuated by the early development of the secondary elements. A good example of this case is seen in *Canavalia ensiformis* (Text-fig. 43, B), and *C. lineata* (Text-fig. 43, C), in which conducting elements (vessels) are only in the portions opposite to the primary woods, the spaces between these being filled with secondary fibrous elements arranged in radial rows. In comparing this situation with examples having no such secondary elements (e.g. many other species of *Phaseoleæ*: *Rhynchosia volubilis* (Text-fig. 41, C), *Pueraria Thunbergiana* (Text-fig. 44, V), etc.), the relationship between the case of a continuous ring and that of the bundles disposed separately on a circle seems to be quite clear.

Here, we must add a series where the bundles are disposed in the slender part of the petiole; such are found only among the closely related genera of *Amherstieæ* and *Bauhinieæ* and are intimately correlated to the conditions in the basal part of the petiole mentioned in the preceding lines under the letter "δ". The simplest case of this arrangement is characterized by the prescence of a slight invagination on the ventral side of the vascular circle (*Bauhinia acuminata* (Text-fig. 12, I), *Tamarindus indica* (Pl. V, fig. 8), *Saraca indica* (Text-fig. 10, J), etc.). That such a disposition of the petiolar bundles has an intimate relationship with the arrangement of the formula (5)' is recognized by the fact that *Bauhinia candicans* and *B. alba* take the latter arrangement in the

1) For example, the petiolar bundles in *Indigofera incarnata* (Text-fig. 32, B; and Pl. VI, fig. 18) are disposed separately though they are situated close to each other, while the corresponding segments are clearly discerned in the continuous ring of *Indigofera Kirilowii* (Text-fig. 32, C).

2) These segments which are obscured in the slender part of the petiole, are often clearly observed at the transitional region between the pulvinus and the slender part of the petiole or at the vicinity of the nodule. In the early stage of development shows this fact more clearly.

slender part of the petiole, though they are characterized by the possession of the invagination at the petiolar base. Nearly all of the further varied conditions are represented by the vascular system of *Bauhinia japonica*; that is, the marked invagination in the lower part of the petiole (Text-fig. 14, B and C) becomes an amphivasal concentric medullary ringlet at a certain level (Text-fig. 14, D; and Pl. V, fig. 10), while the medullary ringlet and the outer ring changes into a pair of ringlets situated on the ventral side, and a dorsal ellipse (Text-fig. 14, E). The conditions represented by the other species of *Bauhinia* and *Cercis* can be included in one of the above arrangements or one which is slightly different.¹⁾

The last case is represented by *Acacia confusa* in which the petiolar bundles are arranged in two vertical rows as the petiole is transformed into a vertically flattened phyllode (Pl. VIII, figs. 48 and 49).

§§ *Classification of Type III.* We shall now turn to the consideration of the vascular system in the petiolar base and the slender part of the petiole. In the following lines, the subtypes of Type III are given by combining the conditions in the petiolar base and that of the slender part of the petiole, and the characteristics of each of these subtypes are briefly summarized together with a few examples:—

- A. In the slender part of the petiole, five main bundles are arranged on an arc or circle (formula (2)) or the petiolar stele takes the form of a continuous arc or ring derived from the former type (formula (2)').
 - (a) The foliar traces are directly fused into a continuous arc or ring at the petiolar base (α).....*Cladrastis lutea*, *Robinia hispida* (rarely), *Arachis hypogaea*, etc.
 - (b) The foliar traces are fused into a continuous arc or ring, both extremities of the arc or the ventral portion of the ring being composed of the elements which are transferred from the marginal portion of each original foliar trace (β).....*Styphnolobium japonicum*, *Platysprion platycarpum*, *Indigofera incarnata*, *Robinia pseudacacia*, *Desmodium racemosum*, *Pongamia glabra*, *Rhynchosia volubilis*, etc.
- B. The arrangement of the petiolar bundles in the slender part of the petiole is given by the formula (3) or (3)'.
 - (a) The condition in the petiolar base is the same as the case of A(a).....*Thermopsis fabacea*, *Baptisia australis*, *Caragana Chamlagu*, etc.
 - (b) The condition in the petiolar base is the same as the case of A(b).....*Crotalaria usaramoensis*, *Laburnum vulgare*, *Melilotus suaveolens*, etc.

1) The relationship between these arrangements can be understood by referring to the description of these species (cf. pp. 249–255).

- C. The arrangement of the petiolar bundles in the slender part of the petiole is given by the formula (4) or (4)'.
- (a) The condition in the petiolar base is the same as the case of A(a).....
Kummerowia striata, etc.
 - (b) The condition in the petiolar base is the same as the case of A(b).....
Cassia mimosoides var. *nomame*, *Indigofera Dosua*, *Wistaria japonica*, *Lespedeza tomentosa* (mostly), *L. cuneata*, *Clitoria ternata*, etc.
- D. At the petiolar base the foliar traces are fused into a continuous arc or ring provided with a few medullary bundles which are sooner or later inserted into the ring or arc (γ), and the arrangement of the petiolar bundles in the slender part of the petiole is given by the formula (2) or (2)'.....*Erythrina crista-galli*, *Pueraria Thunbergiana*, *Phaseolus multiflorus*, *Vigna sinensis*, etc.
- E. At the petiolar base the foliar traces are fused into a continuous ring or arc as in the case of A(b), and the arrangement of the petiolar bundles in the slender part of the petiole is given by the formula (5)_{a-c} or (5)'.....*Albizia Julibrissin*, *Pithecolobium dulce*, *Acacia villosa*, *Mimosa pudica*, *Adenanthera microsperma*, *Ceratonia Siliqua*, *Hæmatoxylon Campechianum*, etc.
- F. At the petiolar base, either the foliar traces are fused into a ring having a more or less marked invagination on its ventral; or the invaginated portion develops into the medullary bundles; or it develops into much more complicated forms which are closely related to the former two cases.
- (a) The arrangement of the petiolar bundles in the slender part of the petiole is given by the formula (5) or (5)'.....*Saraca indica*, *Bauhinia alba*, *Bauhinia candicans*, etc.
 - (b) In the slender part of the petiole, the invagination is retained, or takes the forms closely related to the former conditions.....*Amherstia nobilis*, *Tamarindus indica*, *Bauhinia japonica*, *B. purpurea*, *Cercis chinensis*, etc.
- G. The condition in the petiolar base is the same as the case of A(b), and, according to the form of the petiole which is transformed to form a vertically flattened phyllode, the bundles are arranged in two rows, and the xylem of bundles in a row faces those of another.....*Acacia confusa*.

§ On the relationship between the various vascular systems in the basal and slender parts of the petiole, and the distribution of these types among the natural systematic groups. It has been frequently mentioned in the preceding article, that there are seen several forms, transitional from a condition belonging to one subtype to another subtype also belonging to the same type. We shall now consider the relationship between the various conditions belonging to the different types.

Among the three types, which have been assumed for the sake of convenience, there can be found some intimate relation between each condition of Type II and that of Type III; that is, the difference between these two types chiefly depends on the fact that, in Type III, owing chiefly to the presence of

the pulvinus at the petiolar base, the foliar traces are fused into a continuous arc or ring at this region; as a natural consequence, therefore the derivation of the bundles in the slender part of the petiole from the original foliar traces is somewhat obscured, while, in Type II, the derivation of the petiolar bundles from the original foliar traces, can easily be traced by the characteristic feature of this type. However, considering only the topographical situation of the petiolar bundles, we can easily see that there are several exactly corresponding situations between Type II and Type III.¹⁾

Taking Type II-A (a) and Type III-A (a), as an example, we find that both cases show the same arrangement of the petiolar bundles, consisting of five main bundles or of corresponding segments (m, l_1, l'_1, l_2, l'_2). When we consider Type II-A (a), in which, at the base of the petiole, the foliar traces approach nearer and nearer to each other until at last they are fused into a single one, the condition thus formed unmistakably represents that of the Type III-A (a). So it is not incorrect to consider that Type III-A (a), in which the foliar traces are fused into an arc in the transverse section, is derived by fusion in the manner indicated with broken lines in the diagram (Text-fig. 50, A); in other words, when the condition shown in this diagram is cut along the broken lines and stretches towards both lateral direction there is formed the condition of Type II-A (a). In the Type III-A (a), the transition from the continuous arc to the continuous ring can easily be derived by the closure of the arc.

Thus, comparing them in the same way, the relationship between the Type II-B (a) and Type III-B (a), and that between the Type II-C (a) and Type III-C (a) can easily be recognized.

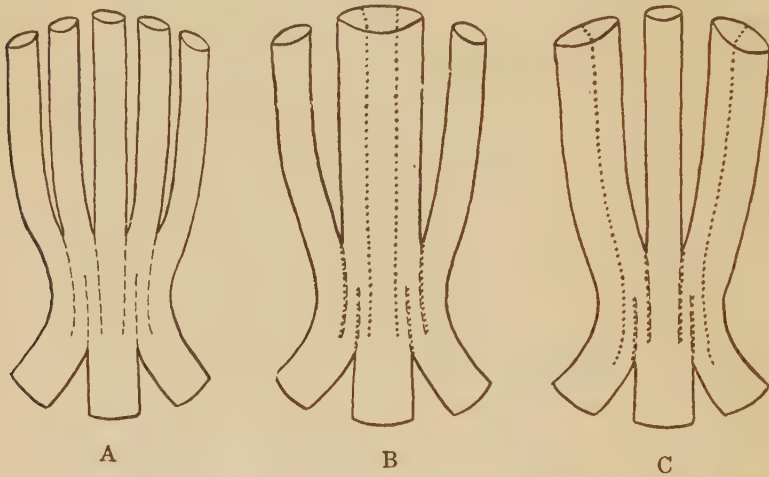
In the diagram (Text-fig. 50, B and C), these relationships are illustrated, in which the broken lines show the derivation of Type III-B (a) and Type III-C (a) respectively from the Type II-B (a) and Type II-C (a), while the dotted lines show the relationships between the former two types and Type II-A (a) or III-A (a).

Consequently, it can also easily be recognised that Types III-A (b), III-B (b), III-C (b), and III-D have a close relationship with Types II-A (b), II-B (b), II-C (b), and II-D.

1) To determine whether an arrangement of the petiolar bundles in a type is the same as that of another, the observation of the topographical condition in the transverse section of the slender part of the petiole seems to show sufficient characteristics in most cases; but a much more definite determination is given by the behaviour of the petiolar bundles at the nodule.

Within the extent of my present investigation, there are no examples in Type II corresponding to Types III-E and F which seem to be derived by the fusion of the lateral bundles l_2 and l'_2 and by some further modification. Also Type III-G seems to have an intimate relation, in comparison with the other species of *Acacia*, with the case of type III-E.

The relationships between the various conditions included in Types II and III seem to be much more clearly signified by looking over the distribution of these types among the natural systematic groups (cf. Tab. IV).



Text-fig. 50. Diagrams showing the relationships between Types II and III. Explanations in text.

Subfam. *Mimosoideæ*:—So far as my observations are concerned, all species among this subfamily belong to Type III-E, except *Acacia confusa* which represents Type III-G owing to the special morphological feature of the petiole.

Subfam. *Cæsalpinioidæ*:—All of *Amherstieæ* and *Bauhinieæ*, belong to Type III-F (a) or (b); in *Cassieæ*, *Cassia Fistula* and *Ceratonia Siliqua*, belong to III-E, and other species of *Cassia*, to III-C (b); in *Eucæsalpinieæ*, three *Cæsalpinia* species represent II-D, and all species belonging to the other genera represent III-E.

Subfam. *Papilionatæ*:—All species of *Sophoreæ* represent Type III-A (a) or (b), and two species of *Podalyrieæ* equally represent III-B (a); in *Genisteæ*, the various conditions belonging to different types are mixed up; that is, *Genista*, *Ulex*, and *Cytisus* represent Type I, *Crotalaria sessiliflora* II-C (b), while others belong to the different types II and III; but they all coincide in the condition

B(a) or (b); in *Trifolieæ*, *Trifolium* shows the Type II-A(a), and *Medicago* and *Melilotus* III-B(b); and *Lotus corniculatus* var. *japonicus* shows Type II-B(a); in *Galegeæ*, Types III-A(b) (rarely A(a)) and III-C(b) are the predominant, while in a few instances, both types are represented even in the same species; but *Caragana* belongs to Type III-B(a), and *Astragalus* to II-B(a) or (b). Also the Type III-A(b) (or rarely (a)) and III-C(b) (or rarely (a)) are widely prevalent in *Hedysareæ*; all of the *Dalbergiæ* represent Type III-A(b), and all of *Vicieæ* belong to II-A(a) or (b) except type II-C(a) which appears rarely in *Vicia bifolia* as an abnormal situation. The prevalent situation in the *Phaseoleæ* is III-A(b), with several examples belonging to III-D; only a species—*Clitoria ternata*—shows the condition III-C(b).

To sum up, the distribution of the various types, hitherto stated, is shown in the following table, in which the number of species belonging to each type is given.

Tab. III.

Types Name of subfam.	II							
	I	A(a)	A(b)	B(a)	B(b)	C(a)	C(b)	D
<i>Mimosoideæ</i>								
<i>Cæsalpinioidæ</i>								3
<i>Papilionatæ</i>	5	10	6	3	3	2	1	

Types Name of subfam.	III										
	A(a)	A(b)	B(a)	B(b)	C(a)	C(b)	D	E	F(a)	F(b)	G
<i>Mimosoideæ</i>								11			1
<i>Cæsalpinioidæ</i>						5		6	3	8	
<i>Papilionatæ</i>	3	35	3	5	1	20	7				

‡ Comparison of these types with those determined by previous investigators.

Though there are many works on the study of the vascular system of petioles of leguminous and other dicotyledonous ones, most investigators have only made observations of the topographical disposition of petiolar bundles in single trans-

verse section through a certain definite region; at present, therefore we have comparatively few observations on the vascular system in the petiole as a whole.

I shall give below a brief comparison of the types observed in the present study with those determined by some previous authors.

Reference to Type I in the present study:—In his investigation on the vascular system in dicotyledonous petioles, ACQUA (1887) regarded the case having a single foliar trace as Type 1,¹⁾ which corresponds to Type I in the present study. Though only *Ulex europæus* was reported by him, yet I found a few species including a few genera closely related to *Ulex*; this condition seems to be one of the most prevalent among the dicotyledonous species. So far as the vascular system in the petiolar base and the slender part of the petiole is concerned GERRESHEIM's 1. Typus (*Polemonium cœlureum*) seems to correspond to ACQUA's Type 1.

To Type II:—In regard to his Type 4 b, ACQUA briefly summarized as follows:—"Inserzione per tre cordoni i quali si anastomizzano nella base del picciuolo o nell'uscire della corteccia.....; a).....; b) nelle picciolate, intrecciandosi e dividendosi variamente formano o un arco o una cerchia, c)....."²⁾ His type includes nearly all cases that in the present study have been classified as Type II together with part of Type III. The vascular systems in *Vicieæ*, which have been treated as Type II-A(a) or (b) in the present study, was regarded as an independent type—Type 10³⁾—because the lateral foliar traces ran through an internode as the cortical bundles. RIPPEL (1913) preferred *Trifolium elegans* as the representative of his 7. Typus and he gave the short characteristic of this type as "3 Bündelige Blattspur. Im Blattgrund nur eine ganz schwache bogenförmige Bündelverbindung.....". From his description

1) L'inserzione della foglia sul fusto si fa per un solo cordone o per un solo gruppo di fasci, il quale uscito dalla corteccia si divide per dare origine alle nervature nelle foglie sessili. Nelle foglie picciolate traversa il picciuolo o indiviso o presentando varie divisioni per le quali si possono avere più fasci disposti ad arco o in forma di cerchia più o meno completa. Nel lembo dalle estremità dell'arco o dai lati della cerchia partono le nervature.

2) He attributed the following leguminous species to this type; namely, *Erythrina crista-galli*, *Cicer arietinum*, *Trifolium pratense*, *Medicago sativa*, *M. arborea*, *Lotus jacobæus*, *L. corniculatus*, *Hippocrepis comosa*, *Dolichos lignosus*, *Hæmatoxylon campechianum*, *Nissolia fruticosa*. He showed that this type was also found in some species of *Urticaceæ* and *Euphorbiaceæ*.

3) Type 10: "L'inserzione dei fasci fogliari nella cerchia del fusto si ha in più di un internodio. Anastomosi e formazione nel picciuolo di un arco o di una cerchia; ovvero fasci disposti linearmente".

and illustration, it is clear that the connection of the foliar traces coincides with my Type III-A(a); but, according to my observations of other species of *Trifolium*, it seems that there are considerably marked mutual connections at the petiolar base. GERRESHEIM (1913) stated in his 5. Type in which *Vicia Faba* was put forward as the representative, "Der Blattgrund, der an den anderen Typen, eine Stelle wichtiger Bündelverbindungen ist, enthält bei *Vicia* nur eine Bündelspaltung:....." However my observation coincides with ACQUA's description and illustration in that there is an important connection between each foliar trace.

To Type III:—As his Type VII (the third type of his "types complexes"), PETIT (1887) gave the following general features:—"le système libéro-ligneux débute par trois faisceaux. De chaque faisceau latéral naît un fascicule; il en part deux du faisceau median. Ces quatre fascicules, en se sondant deux à deux, donnent naissance à deux faisceaux qui se portent en haut. Les trois faisceaux primitifs se soudent et forment à la caractéristique un arc de cercle, dont les faisceaux supérieurs occupent la corde", and this type clearly includes a case of Type III-A(b), B(b), C(b), D, E, F(a), or F(b). He found this condition in *Viburnum* and in many arborescent and frutescent species of *Leguminosæ*. From the results of my present observation, however, this condition prevails among the leguminous species, not only in arborescent and frutescent species, but also in many typical herbaceous ones, e. g. *Cassia mimosoides* var. *nomame*, *Desmodium racemosum*, *Rhynchosia volubilis*, etc. Moreover, there seems to be no reason, why *Apios*, *Phaseolus*, *Erythrina* should be attributed by PETIT to his Type III¹⁾ (the third type of 'types simples'), while many arborescent and frutescent species have been classified under Type VII.²⁾ A part of my Type III F(a) or (b) which includes the complicated vascular system in *Bauhinia* and *Amherstia*, are treated by PETIT as an independent type—Type XII (the last one of 'types complexes'), which is characterized by the vascular system in *Cercis siliquastrum* and *Bauhinia racemosa*. As was mentioned above, ACQUA's Type 4b includes the species, without ridge bundles, of a part of my Type III, namely, *Erythrina crista-galli*, *Medicago sativa*, *Hæmatoxylon campechianum*. The case in which a trilacunar condition with ridge bundles is seen, ACQUA has

1) Summarising the character of his Type III, PETIT stated "Faisceaux soudés en anneau à l'initiale, devenant par leur divergence distinct à la caractéristique".

2) This contradiction seems to depend chiefly upon the difficulty of the practical determination of the so-called 'initiale' in a single transverse section, owing to the rapid changes of the topographical disposition of the bundles in the petiolar base.

summarized as his Type 5.¹⁾ This Type includes nearly all members of my Type III-A E having ridge bundles, as well as the comparatively simple case of F(a) or (b).²⁾ The complicated cases of F(a) or (b) are included by ACQUA in his Type 6 which is briefly summarized as "Inserzione e anastomosi come sopra, formazione di una cerchia con cordoni corticali e midollori" (*Bauhinia purpurea* and *B. glandulosa*), while in regard to his Type 9, which corresponds to my Type III-G, he says "Inserzione e anastomosi come nelle altre forme precedenti. Si ha nel cuscinetto una cerchia la quale in sequito si allunga e subisce numerose divisione. Picciuoli trasformati in fillodi³⁾". He especially established an independent type—Type 11⁴⁾—for the species having five gaps (*Pueraria Thunbergiana*, *Phaseolus vulgaris*, and *Dolichos giganteus*).

Though it is not the species of leguminous plants, the condition of 4. Typus "*Liquidamber styraciflua*" stated by RIPPEL (1913)—"Im Blattgrund Verzweigungen und Durchkreuzungen; in Blattstiel Zusammenschluss zu einen Bündelrohr.," and the 10. Typus "*Dictamnus albus*" determined by GERRESHEIM and the vascular system in *Viburnum cotinifolium* which is mentioned by him in connection with the 10. Typus, show a close relationship with the case of Type III-A(b) or E in the present study.

D. The Ridge Bundle.⁵⁾

In many species of this family, the slender part of the petiole and internodes are characterized by the presence of more or less conspicuous ridges and grooves. According to the presence of the ridges—though in several instances they are very vague—there is almost always found a small bundle which normally takes the collateral structure and is accompanied by a well-

1) The characteristics of his Type 5 are as follows:—"Inserzione e anastomosi come sopra, formazione o di un arco o di una cerchia con cordoni corticali", and the following 15 species were attached to this type, namely, *Wistaria rubra*, *W. chinensis*, *Mimosa pudica*, *M. denhardtii*, *Anthyllis barbajovis*, *Robinia pseudacacia*, *Sophora japonica*, *Parkinsonia aculeata*, *Acacia cornigera*, *A. farnesiana*, *Ceratonia Siliqua*, *Desmodium gyrans*, *Tamarindus indica*, *Bauhinia racemosa*, and *B. aculeata*.

2) That is, the case having a slight invagination on the ventral portion of the vascular ring in the slender part of the petiole.

3) The following 13 species were attached to his Type 9; namely, *Acacia linearis*, *A. melanoxylon*, *A. saligna*, *A. rostellifera*, *A. calamifolia*, *A. crassifolia*, *A. iteaphylla*, *A. homomulla*, *A. cultriformis*, *A. mirbeli*, *A. obliqua*, *A. ornithophora* and *A. oxycedrus*.

4) "Inserzione della foglia per cinque cordoni, i quali il più delle volte si anastomizzano nel passare alla foglia".

5) cf. The terminology, p. 232.

developed bundle of mechanical elements.¹⁾ From the fact that such bundles are intimately related to the presence of the ridge, the writer called them the "ridge bundles", and their presence or absence in the slender part of the petiole and internodes in each species were respectively designated by + and - in Tab. IV. Though the presence or absence of the bundles is very irregular, even in a genus, as may be recognized by the table, yet several facts of much interest have been observed, which will be briefly stated below.

‡ **Departure of the ridge bundles at the petiolar base.** As usual, the ridge bundles are separated from the petiolar bundles which are arranged in various ways at the transitional region between the pulvinus and the slender part of the petiole. The mode of departure of the ridge bundles in this region is most interesting because there is found to be a marked difference between the sub-families *Mimosoideæ* and *Papilionatæ*; in the former they depart from the widely separated portions of the ventral side of the vascular ring or circle,²⁾ and between these two points of departure there remains a large segment consisting of a large portion of the main bundle;³⁾ in all cases, they have their origin in the original lateral foliar strands.

On the other hand, there remains either only a single or a couple of feeble segments between the departing points of the ridge bundles (e. g. *Styphnolobium japonicum*, *Maackia amurensis* var. *Buergeri*,⁴⁾ or the ridge bundles depart just

1) Sometimes, it represents an amphivasal concentric structure through a part or the whole course of the petiole and rachis. In such cases the fibrous element completely surrounds the bundle.

2) In *Mimosoideæ*, the foliar traces are always fused into a continuous ring in the pulvinus and the arrangement of the petiolar bundles in the slender part of the petiole is represented by the formula (5) or (5)' except *Acacia confusa*.

3) These conditions may be easily recognized from a series of microphotographs (*Mimosa pudica*) representing the transverse section through the middle portion of the pulvinus (Pl. V, fig. 4), the transitional region between the pulvinus and the slender part of the petiole (Pl. VIII, fig. 37), and the middle portion of the slender part of the petiole (Pl. VII, fig. 31). Also the same condition is well-illustrated in *Albizia Julibrissin*; that is, at the transitional region, the continuous ring in the pulvinus (Text-fig. 1, H) diverges to separate into a large bundle situated on the ventral side and an open arc on the dorsal side (Text-fig. 1, I), and then the ridge bundle issues from each end of the arc which, at the same time, is divided into three (Text-fig. 1, J).

4) This case may clearly be seen in a series of figures showing the transverse sections through the successive levels of the transitional region of *Styphnolobium japonicum* (Text-fig. 21, F and G). In *Styphnolobium japonicum* and *Sophora japonica*, two sets of ridge bundles respectively issue from closely successive levels. In the former species, they are soon fused into a pair, and in the latter the bundles occurring at the higher level are situated between those occurring at the lower level.

from the middle of the ventral portion of the ring or circle (e.g. *Wistaria japonica*, *Robinia pseudacacia*, *Desmodium racemosum*, *Lespedeza tomentosa*,¹⁾ or they depart from both extremities of the arc (e.g. *Thermopsis fabacea*, *Crotalaria usaramoensis*,²⁾ in any case, the segment remaining between their departing points can not be considered as the chief member of the petiolar bundles. The constitution of the ridge bundles in the slender part of the petiole derived from the original foliar traces is various owing to the ways of fusion of the foliar traces at the petiolar base; in some instances, they have their origin in the original lateral foliar traces as in the case of *Momosoideæ*, and in others they arise from the original median foliar trace. Moreover, in several instances they are composed of both original lateral and median foliar traces.

In the subfamily *Cæsalpinioidæ*, both modes of the departure of the ridge bundles are found; that is, all the investigated species of *Cassia*, except *Cassia Fistula*, belong to the latter category, and others to the former.

‡ **The behaviour of the ridge bundles.** In many species of *Mimosoideæ* (e.g. *Albizzia Julibrissin*, *Acacia villosa*, *Mimosa pudica*, *Adenanthera microsperma*, etc.), *Cæsalpinioidæ* (e.g. *Cassia torosa*, *Cassia Fistula*, *Gleditschia japonica*, etc.), and some species of *Papilionatae* (e.g. *Styphnolobium japonicum*, *Maackia amurensis* var. *Buergeri*, *Wistaria japonica*, etc.), the ridge bundles which arose from the petiolar base continue through the slender part of the petiole and internodes, and at each nodule, each of these bundles issues minute fascicles which are joined to the vascular supply to a leaflet; in species having the stipels, stipelar traces issue from the ridge bundles.³⁾ In some instances, these ridge bundles are connected with each other by a few small fascicles at each nodule⁴⁾ (e.g. *Albizzia Julibrissin*, *Maackia amurensis* var. *Buergeri*, *Wistaria japonica*, etc.), while in some others, the ridge bundles in the higher internodes are often fused into a single one⁴⁾ (e.g. *Pithecolobium Saman*).

1) This case is shown in the diagrammatical reconstruction of the vascular system and the figures showing the transverse section of the transitional region in *Desmodium racemosum* (Text-fig. 35, B) and *Lespedeza tomentosa* (Text-fig. 35, A; Text-fig. 34, A-C). Moreover, this condition is well-illustrated in a series of microphotographs showing the departure of the ridge bundles in the transitional region of *Robinia pseudacacia* (Pl. VIII, figs. 38 and 39).

2) Such a case may clearly be recognized from the figure showing the transverse section through the petiolar base of *Thermopsis fabacea* (Text-fig. 23, C).

3) In any case, the fascicles from the ridge bundles join to the outermost margins (or corresponding portion when the trace for the leaflet takes the form of a ringlet in the transverse section) of the trace for a leaflet.

4) In *Sophora angustifolia*, there are a few ridge bundles as mentioned above, and they are anastomosed with each other at each nodule, but at the higher internodes these bundles are fused into a pair (Text-fig. 21, T and U).

In some species having pinnately trifoliolate leaves, such as *Desmodium racemosum*, *Lespedeza tomentosa*, *Rhynchosia volubilis*, etc., belonging to the tribes *Hedysareæ* and *Phaseoleæ*, and also *Euchresta japonica* in *Dalbergiæ*, a part of the ridge bundles of the petiole directly enters the lateral leaflet, and join with the vascular entanglement which is formed from a small bundle that issues from the ventral side of the petiolar stele just below the nodule; the vascular elements also issue from the ventral side, just above the level where the small bundle departs. If there are stipels, the traces branch from the ridge bundles before they fuse with the above-mentioned vascular entanglement. The ridge bundles in the internodule are newly caused from the vascular entanglement. Such a situation may easily be recognized from the diagrammatical reconstruction of the vascular system in *Lespedeza tomentosa* (Text-fig. 35, A) or *Desmodium racemosum* (Text-fig. 35, B). The condition in each nodule in *Erythrophleum guineense* (Text-fig. 9, A-F), *Tephrosia candida*, *Milletia taiwaniana* (Text-fig. 32, N-R), *Pongamia glabra*,¹⁾ and *Derris elliptica* seems to belong to the same category.

In *Mucuna Toyoshimai*, contrary to the absence of the ridge bundles in the slender part of the petiole (Text-fig. 42, A), such bundles issue from the vascular complex at the nodule, and they continue through the whole length of the internodes (Text-fig. 42, B). From such behaviour, the bundle that issues from the ventral side of the stele just below the nodule can be considered as a bundle having the same significance as the ridge bundles. If this deduction is sound, the bundle which occurs at each nodule in *Cæsalpinia* species seems to show a peculiar situation of the ridge bundles; that is, the ridge bundles in these species are arranged on the stele, as in a latent state. This consideration seems the more probable when we recall the case of *Platyosprion platycarpum* in which the separation of the ridge bundles from the stele within the slender part of the petiole is usually imperfect (cf. p. 266 sqq.). In *Dumasia truncata*, although the petiole and the internode are characterized by distinctly eminent ridges, there are seen no ordinary ridge bundles, but these ridges are only provided by the bundles consisting merely of mechanical elements. In *Hæmatoxylon campechianum*, and *Poinciana regia*, the separation of the ridge bundles from the normal arrangement of the petiolar bundles is imperfect along a certain length

1) In this species, the small bundle which issues from the ventral portion of the stele just below the nodule is not always single but there occur two small ones, between which a small segment of the vascular ring is left (Pl. VII, fig. 36).

of the slender part of the petiole, but *Gleditschia japonica* seldom show such a situation.

E. The Vascular System in the Petiolar Top and Rachis.

§ The vascular system in the petiolar top of the palmately nerved or compound leaves and that of the single leaflet. The top of the petiole in the palmately nerved or compound leaves, as well as the nodules of the pinnate leaves is generally the most important region where the marked changes of the topography of the vascular bundles take place, except in some examples with palmately trifoliate leaves or with a single leaflet. Such simple cases are represented by several species of *Genisteæ*; in *Crotalaria sessiliflora*, for example all petiolar bundles directly enter the lamina undergoing no further changes, while in *Genista*, *Ulex*, and the case of a single leaflet of *Cytisus Scoparius*, a single bundle coming out from the single gap of the stem directly enters the lamina in which it branches; for example, in *Cytisus Scoparius*, a single bundle that issues from the stem is, sooner or later, according to the sessil or petioled condition, divided into three equal parts, proportional to the three leaflets (Text-fig. 27, J and M). In other plamate leaves, however, the condition in this region is somewhat complicated, and in the following lines, I shall state these conditions beginning with the case of palmately trifoliate leaves.

§§ *Palmately trifoliate leaves.* The condition in the petiolar top of this type is shown in diagrammatical illustration (Text-fig. 51, A-D) exemplifying the case in which the main petiolar bundles (m, l_1, l_1', l_2, l_2') are disposed separately in the slender part of the petiole. On the right hand of the diagram a bundle fm issues from a lateral petiolar bundle l_1 situated near the median one, and on the other hand fl_1 and fl_2 branch successively from the other lateral bundle l_2 (Text-fig. 51, B); they then enter the petiolule of the leaflet as a single strand which takes the form of a continuous arc or ringlet in transverse section (Text-fig. 51, C and D).¹⁾ The vascular supply to the left leaflet issues from l_1' and l_2' in the same manner. The remains of all lateral bundles (l_1, l_1', l_2, l_2') and all the median ones are fused to form the bundle for the median leaflet. The remains of l_1 and l_1' are often very feeble or altogether absent, and sometimes the branches of the median bundle strengthen these remains. This con-

1) If the ridge bundles are present, one of them is divided into two, each of which is fused with each margin of the bundle for the lateral leaflet, or is inserted into the ventral portion of the ringlet.

dition is typically represented by *Trifolium repens* and *Tr. pratense* (cf. the diagrammatical reconstruction of the whole vascular system of *Trifolium repens*: Text-fig. 28, C).

Though the disposition of bundles in the slender part of the petiole differs from the former case, the condition in the petiolar top of *Thermopsis fabacea*, *Crotalaria usaramoensis*,¹⁾ and *Laburnum vulgare*—all of which represent the condition (3) or (3)' in the slender part—can also be included in the case of five main bundles (the arrangement of the petiolar bundles shown by the formula (2) or (2)') as was described and illustrated in the preceding descriptive part (cf. Text-fig. 23, E-G, I-J; Text-fig. 24, Q-U; and cf. pp. 268-270). Again, from such behaviour, the relationship between (2) or (2)' and (3) or (3)' may be much more clearly confirmed.²⁾ Also, the fact that the large lateral bundles in the case of (4) or (4)' (e.g. *Kummerowia striata*) must be considered as a case in which two pairs of lateral bundles (in the case of (2) or (2)') are fused into a pair is recognized not only by the condition in the petiolar base, but much more clearly by the condition in the petiolar top; because here, as also for the vascular supply to the lateral leaflet, the lateral bundle is divided at the middle portion and both halves act as the bundles exactly corresponding to the l_1 and l_2 (or l_1' and l_2') in the case of (2) or (2)'.³⁾ Here I shall consider the constitution of bundles for the three leaflets and the relationship between the former and the original foliar traces. Taking first the case of the Type II-A (a) (or III-A (a)), in the basal and slender parts of the petiole, the lateral bundle l_1 or l_2' is, as has already been stated, composed merely of one of the lateral foliar traces, and the median petiolar bundle m merely of the median foliar trace, while the lateral bundle l_1 or l_1' is composed of both lateral and median ones; so that the bundles for each lateral leaflet consists of the original lateral foliar trace, and that for the median one contains both lateral and median foliar traces; that is, both the marginal portions of the arc (or the ventral portion of the ringlet) are provided by the original lateral foliar trace, and the dorsal part, by the original median one. Also, the constitution of the bundle for each leaflet in the case of *Thermopsis fabacea* and *Kummerowia striata* is entirely the same, though they respectively represent Types III-B (a) and III-C (a) in the basal and slender part of the petiole. In several instances, however—for example in

1) In this species, the condition in the petiolar top shows some abnormalities, but is fundamentally attributed to the case of *Thermopsis fabacea* (cf. p. 270).

2), 3) Of course the same facts are found not only in palmately trifoliate leaves but also in any type of leaves.

Laburnum vulgare—the bundles situated on the ventral side of the petiole and those corresponding to the l_2 and l_2' in the case of the five main bundles, are composed of each marginal portion of the original three foliar traces; and though the elements that come from these foliar traces lose their individuality by fusion, all petiolar bundles seem to rearrange themselves into three bundles for each leaflet, corresponding approximately to the original three foliar traces.¹⁾



Text-fig. 51. A-D, diagrammatical illustration showing the topographical changes of the bundles in the pet. top of palmately trifoliate leaves. E-H, that in a nodule of pinnate and bipinnate leaves. I-L, that in the pet. top of even pinnate or bipinnate leaves with a single pair of pinnae. Explanations in text.

§§ *Palmate leaves with many leaflets.* In this case, usually, a definite number of bundles, proportional to the number of leaflets, is transformed from the petiolar bundles m , l_1 , l_1' , (or corresponding part) by their division, and at the same time, the bundles l_2 and l_2' are also divided into a definite number of branches (twice the number of the leaflets). Then, to each margin of the former bundles, a branch, as stated above, is respectively fused. Such a condition may easily be recognized by the diagrammatical reconstruction of the vascular system and transverse sections through the petiolar top of *Lupinus hirsutus* (Text-fig.

1) The same fact in *Liquidamber styraciflua* is well-expressed by RIPPEL's description (1913):—".....In der Spreitenbasis werden bei Bildung der Nervenbündel die Blattgrund vorkommenden Durchkreuzungen wieder rückgängig gemacht".

26, B; Text-fig. 25, H-L; and Pl. VIII, figs. 44-46); also by a series of figures representing transverse sections through the petiolar top of *Laburnum vulgare* (Text-fig. 24, H-K: these figures show an abnormal case in which the leaflets are five in number). Though as to the distribution of the elements from the original foliar traces to each leaflet, we cannot make a sweeping statement, because it varies proportionally to the condition at the petiolar base, yet it seems to suggest that a few leaflets situated on both sides are supplied by the original lateral foliar traces and those situated on the median chiefly by original median foliar trace.

§§ *The palmately nerved leaves.* This type of leaf is seen only in *Cercis* and *Bauhinia*. In contrast to external-morphological differences between the palmately nerved and compound leaves, the vascular systems in the petiolar top in these two leaf-types show a marked coincidence with each other. In *Bauhinia*, there are found, at the top of the petiole, a pair of large bundles with a pair of smaller ones between them, which are formed by the invagination of the large ventral bundle (Text-fig. 12, G and H).¹⁾ The larger bundles ramify into a definite number of palmate nerves and both smaller bundles are also divided into a definite number amounting to twice that of the larger bundles, the lateral margins of each nerve being composed of these branches (see Text-fig. 13, A). The vascular system in the petiolar top of *Cercis* is, except for the vascular supply to the midrib, nearly the same as that of *Bauhinia* (Text-fig. 15, M). When the diagrams representing the vascular systems in the petiolar top of *Bauhinia* and *Cercis* are compared with that of *Lupinus* (Text-fig. 26, B), it can easily be recognized that there are only a few slight differences among these three diagrams; these three conditions therefore can fundamentally be placed in the same category.

§ *The vascular system in the nodules and internodes of the odd-pinnate and even-pinnate or bipinnate leaves.*

§§ *Pinnately trifoliolate leaves.* The condition in the nodule of the pinnately trifoliolate leaf can fundamentally be classed with that in the petiolar top of the palmately trifoliolate leaves; that is, the condition of the vascular supply to the lateral leaflets is generally the same in both leaf-types, while that to the median leaflet is also the same so long as one limits the consideration only to the constitution of the bundles from the original foliar traces. Their respec-

1) Consequently, these bundles correspond to the lateral bundles l_2 and l_2' in the case of five main bundles.

tive vascular systems differ only in the fact that, in the pinnately trifoliolate leaf the bundles enter the median leaflet after having passed through the internode. The relation of the vascular supply to the leaflets and the topographical situation of the bundles in the slender part of the petiole are also in accordance with that stated in the case of the palmately trifoliolate leaves.¹⁾ Though there are some exceptions, the arrangement of bundles in the internodes of the pinnately trifoliolate leaves usually show the condition represented by the formula (4) or (4)' (cf. Tab. I.). The lateral bundles in the internode in some instances are respectively formed by the fusion of the remains of the lateral petiolar bundles l_1 , l_2 , and l'_1 , l'_2 (or the segments corresponding to these bundles), or, in some others, a part of the median petiolar bundle strengthens the former. The condition in the node and internode in these cases in which the arrangement of petiolar bundles may be given with the formulae (2), (3), and (4), is respectively shown in the diagrammatical reconstruction of the whole vascular system of *Desmodium racemosum* (Text-fig. 35, B), *Melilotus suaveolens* (Text fig. 29, A), and *Lespedeza tomentosa* (Text-fig. 35, A). From these diagrams, these facts can easily be recognized. The behaviour of the ridge bundles at the node, the vascular entanglement on the ventral side of the node in connection with the ridge bundles, and the origin of new ridge bundles in the internode have already been discussed above (cf. p. 338 sqq.). Among *Phaseoleæ*, though the vascular system in the node and internode in many species is the same as the case of *Desmodium racemosum*, etc. (e. g. *Rhynchosia volubilis*), in several examples the vascular entanglement is seen not only on the ventral side, but also on both lateral sides, while a small part of the median bundle seems to add to the vascular supply to the lateral leaflets (e. g. *Dolichos Lablab*, *Vigna sinensis*, etc.).¹⁾ Moreover, in several species in this tribe, there are a few medullary bundles which run through a part or the whole length of the petiolule of leaflet (e. g. *Glycine Soja*, *Erythrina crista-galli*, *Apios Fortunei*, *Pueraria Thunbergiana*, *Dolichos Lablab*, etc.). Though it seems to bear no direct relations, yet it is a fact of interest that, in some of these species or in closely related ones, medullary bundles appear in the pulvinus (cf. Type III-D, p. 322 and 332).³⁾

1) As was stated in the case of palmately trifoliolate leaves, this fact is an important requisite for manifesting the relationships between the various condition of the arrangement of the petiolar bundles.

2) This condition is indicated by the sign Do. in Tab. I (p. 309).

3) The presence of medullary bundles in the petiolule of the leaflet is rarely found in species belonging to other tribes as will be stated below.

?? *Odd-pinnate leaves with many leaflets.* In this are considered cases ranging from those carrying five leaflets to those carrying many. The vascular supply to the lateral leaflet takes place generally, from the lateral bundles l_1 and l_2 (or l_1' and l_2') or from corresponding segments, in the same way as in the case of pinnately or palmately trifoliate leaves in one or a few lower nodules, while the median bundle is altogether independent of the vascular supply (Text-fig. 51, E-H).¹⁾ At the nodule higher up, the lateral bundle l_1 or l_1' which is reduced by the vascular supply for the pinnae is reinforced by branches of the median bundle, so that the elements of l_1 and l_1' in the lateral bundles in the internodes are gradually replaced by those of the median bundle m . In the higher nodules, however, the bundle fm which forms a main part of the vascular supply to the leaflet comes in most cases directly from the median bundle. The bundles in the uppermost internode enter the terminal leaflet as a single strand. Thus, considering the distribution of the original foliar traces to the leaflets in the case having a somewhat large number of leaflets, those on a few lower nodules are supplied by the original lateral foliar traces, while the others take their supply chiefly from the original median trace. The behaviour of the ridge bundles and those conditions intimately related to the former ones have already been discussed in the article concerning the ridge bundle.

?? *Even-pinnate or bipinnate leaves with a single pair of pinnae.* In general cases, a more or less conspicuous, lanceolate or subulate terminal appendage is found between a single pair of pinnae. According to this morphological feature, nearly all bundles in the petiole enter the pinnae; that is, though the fact of the bundles fl_1 and fl_2 (or fl_1' and fl_2') being composed of the l_2 (or l_2') is the same as in the other case stated above, yet the bundle fm (or fm') is formed from all parts of l_1 (or l_1') and nearly a half of the median bundle. On the other hand, the vascular supply to the terminal appendage is usually composed of minute fascicles from the median part of the median bundle, while that of the l_2 and l_2' , together with the branch of the median bundle which joins to l_1 (or l_1') to form the fm (or fm'), also sends minute fascicles to the terminal appendage. The last fascicle, however, is often very feeble, and sometimes it is altogether absent. This condition may easily be recognized from the diagrams (Text-fig. 51, I-L) and from the diagrammatical reconstruction of the whole vascular system of *Vicia unijuga* (Text-fig. 38, A).

1) This is of course a case of a great many pairs of leaflets.

‡‡ *Even-pinnate or bipinnate leaves with many pairs of pinnae.* Except for the uppermost nodule, the vascular system in the nodules and internodes is the same as in the case of odd-pinnate leaves with many pairs of pinnae. For the terminal appendage which is inserted between the highest pinnae, only a few abortive fascicles are generally supplied in the manner stated above. In *Arachis hypogaea*, however, I could not find the terminal appendage. The behaviour of the ridge bundles has been already considered (cf. p. 338 sqq.). We must now review some interesting conditions in the vascular supply to the leaflet of *Erythrophleum guineense*, *Amherstia nobilis*, and *Saraca indica*. Though the main part of the vascular supply to the leaflet in these species also consists of three bundles which correspond to the bundles *fm*, *fl₁*, *fl₂*, (or *fm'*, *fl₁'*, *fl₂'*) stated above, there are a few small bundles which either occupy the invaginated portion on the ventral side of the stele in the petiolule (e.g. *Erythrophleum*, *Saraca*), or form a few medullary bundles in the petiolule (e.g. *Amherstia*). In these species and their allies, this fact seems to suggest some interesting relationship with the presence of invagination or of medullary bundles in the petiolar base, and, in some cases, with the presence of those through the whole length of the slender part of the petiole and internodes (cf. description on the species of *Amherstia* and *Bauhinia*). In *Caesalpinia Sappan*, the departure of the bundle *fl₂* shows a special condition (cf. p. 260). On the other hand, the tendril which is seen in some species of *Vicia* can be considered as an elongated portion of the rachis. The arrangement of bundles in this organ is altogether the same as that in the internodes, and when the lateral branches are present, the vascular supply to them takes place in the same manner as to the lateral leaflets.

* * * *

In short, in any compound leaves, the vascular supply to the pinnae consists mainly of three bundles, in addition to the ridge bundles or some other small bundles. The bundles constituting each nerve of the palmately nerved leaves is also of the same constitution as that of a leaflet in the palmately or pinnately compound leaves.

‡ *Comparison of the various leaf-types from the vascular-anatomical view points.* In the foregoing paragraphs, the vascular system in the petiolar top, or nodules and internodes has been discussed in reference to each leaf-type. The relationship between these leaf-types will now be briefly compared from the view point of the vascular system. As has already been described, the

constitution of bundles for the median leaflet, as well as for the lateral ones, in a palmately trifoliolate leaf exactly corresponds to that for the median leaflet in the pinnately trifoliolate ones; the only difference between these two types lies in the fact that, in the latter type of leaves, the bundles naturally enter the median leaflet after they pass through the internodule. Besides this fact, in certain species (e. g. *Lespedeza cuneata*), the gap between the typical pinnately trifoliolate and typical palmately trifoliolate leaves is connected by leaves having the internodes developed in various stages of development. The intimate relationship between these two leaf-types can easily be recognized by the above-mentioned facts. In other words, the same relationship seems to exist between a palmate leaf with many leaflets and an odd-pinnate leaf having the same number of leaflets; that is, speaking anatomically, the median leaflet and the terminal one, the two leaflets nearest to the median one and those on the highest nodule,, and the leaflets furthestmost from the median one and those on the lowest nodule in the former and the latter respectively receive nearly corresponding vascular elements when we assume that the constitution of the petiolar stele is the same in both cases. So that, the difference between these two types also lies in the presence or absence of the internodes. That the internodes, as well as the slender part of the petiole, are formed only by intercalary elongation after the initials of the pinnae develop to a certain extent in their ontogeny, is recognized by many previous investigators (e. g. EICHLER).^{1), 2)} The facts that the leaves in *Mimosa pudica* show nearly a palmate condition owing to the extreme shortness of the internode, and that the three leaflets on the highest position in *Derris elliptica*, *Glycyrrhiza* sps., *Wistaria japonica* often represent a palmate condition, seem to manifest the close relationship existing between palmate and pinnate leaf-types.

On the other hand, from the fact that the vascular supply to the terminal appendage in even-pinnate or bipinnate leaves—though very feeble and often difficult to discern and even occasionally altogether absent—is composed of the corresponding elements to that of the median leaflet in the palmate leaves or terminal leaflet in the odd-pinnate leaves, there seems to be no need to hesitate to say that the terminal appendage is an abortive leaflet.

1) That the petiole and internodes have anatomically similar natures may easily be recognized by the preceding descriptions.

2) Thus the petiolar top in the palmately compound or nerved leaves can be considered as a region where the nodules are gathered closely, so that, it will be appropriate, to call the petiolar top in this type of leaves "*compound nodules*".

The palmately nerved leaves in *Cercis* and *Bauhinia* can, from the view point of the vascular system, be classed as a case of palmately compound leaves with many leaflets.

F. Table Showing Some External-Morphological and Vascular-Anatomical Features in Each Species.

So as to see the several important external-morphological and vascular-anatomical features among the investigated species at a glance they are represented in the following table (Tab. IV) with signs or abbreviations as shown :

- Tp. Type of plants:— arb arborescent; frut frutescent; herb herbaceous.
- Lt. Leaf-types:— pal palmately compound; s single leaf; o-pin odd-pinnate; e-pin even-pinnate; e-bip even-bipinnate; phyl phyllode; the signs in parenthesis is rare case.
- Pin. Number of pinnae:—In odd-pinnate and even-pinnate or bipinnate leaves, number of the pairs of pinnae is indicated in numerals. In palmate and palmately nerved leaves, number of leaflets or nerves is indicated in numerals within parenthesis.
- Pul. Pulvinus:—+ present; — absent.
- Lg. Number of foliar gaps.
- Pet. Type of the vascular system in the basal and slender part of the petiole:— I, II-A (a), II-A (b), III-G, reference to the Types I, II-A (a), II-A (b), etc. in Part II, C. (p. 316 sq.). The sign within the bracket shows rare cases.
- rb. The ridge bundles:—+ present in the slender part of petiole; (+) absent in the slender part of petiole, but present in nodules or both nodules and internodules; — altogether absent.

Tab. IV.

Name of plants	Tp	Lt	Pin	Pul	Lg	Pet	rb
MIMOSOIDEÆ							
INGEÆ							
<i>Pithecolobium dulce</i>	arb	e-bip	1	+	3	III-E	+
<i>P. Saman</i>	arb	e-bip	2-4	+	3	III-E	+
<i>Albizia Julibrissin</i>	arb	e-bip	6-11	+	3	III-E	+
<i>A. Lebbek</i>	arb	e-bip	6-12	+	3	III-E	+

ACACIEÆ

<i>Acacia arabica</i>	frut	e-bip	10-20	+	3	III-E	+
<i>A. sphærocephala</i>	arb	e-bip	5-9	+	3	III-E	+
<i>A. villosa</i>	arb	e-bip	5-8	+	3	III-E	+
<i>A. confusa</i>	arb	phyl	0	+	3	III-G	—

EUMIMOSEÆ

<i>Mimosa myriophylla</i>	herb	e-bip	5-10	+	3	III-E	+
<i>M. pudica</i>	herb	e-bip	2	+	3	III-E	+
<i>M. Spegazzinii</i>	herb	e-bip	1	+	3	III-E	+

ADENANTHEREÆ

<i>Adenantha microsperma</i>	arb	e-bip	5-10	+	3	III-E	+
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CÆSALPINIOIDEÆ

DIMORPHANDREÆ

<i>Erythrophleum guineense</i>	arb	e-pin	3-4	+	$\begin{Bmatrix} 9 \\ (8, 7) \end{Bmatrix}$	III-E	+
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AMHERSTIEÆ

<i>Saraca indica</i>	arb	e-pin	2-3	+	3	III-F(a)	+
<i>Tamarindus indica</i>	arb	e-pin	∞	+	3	III-F(b)	+
<i>Amherstia nobilis</i>	arb	e-pin	4-7	+	3	III-F(b)	+

BAUHINIEÆ

<i>Cercis canadensis</i>	arb	pal-n	(5-9)	+	3	III-F(b)	—
<i>C. chinensis</i>	arb	pal-n	(5-9)	+	3	III-F(b)	—
<i>Bauhinia alba</i>	arb	pal-n	(7-13)	+	3	III-F(a)	+
<i>B. acuminata</i>	frut	pal-n	(7-9)	+	3	III-F(b)	+
<i>B. candicans</i>	arb	pal-n	(7-9)	+	3	III-F(a)	+
<i>B. Galpinii</i>	arb	pal-n	(7-9)	+	3	III-F(b)	+
<i>B. japonica</i>	arb	pal-n	(7-11)	+	3	III-F(b)	—
<i>B. purpurea</i>	arb	pal-n	(9-15)	+	3	III-F(b)	+

CASSIEÆ

<i>Cassia Fistula</i>	arb	e-pin	4-8	+	3	III-E	+
<i>C. marylandica</i>	herb	e-pin	5-10	+	3	III-C(b)	+
<i>C. mimosoides</i> var. <i>nomame</i>	herb	e-pin	∞	+	3	III-C(b)	+
<i>C. sulphurea</i>	herb	e-pin	5-8	+	3	III-C(b)	+

<i>C. Tora</i>	herb	e-pin	3-4	+	3	III-C(b)	+
<i>C. torosa</i>	herb	e-pin	4-6	+	3	III-C(b)	+
<i>Ceratonia Siliqua</i>	arb	e-pin	2-3	+	3	III-E	+

EUCÆSALPINIÆ

<i>Gleditschia japonica</i>	arb	{ e-pin e-bip }	{ 6-15 4-8 }	+	3	III-E	+
<i>Hæmatoxylon campechi- anum</i>	arb	e-pin	3-4	+	3	III-E	-
<i>Poinciana regia</i>	arb	e-bip	10-20	+	3	III-E	+
<i>Cæsalpinia Bonducella</i>	arb	e-bip	6-12	+	5	II-D	(+)
<i>C. japonica</i>	arb	e-bip	6-10	+	3	II-D	(+)
<i>C. Sappan</i>	arb	e-bip	10-12	+	7	II-D	(+)

PAPILIONATÆ

SOPHOREÆ

<i>Ormosia formosana</i>	arb	o-pin	5-9	+	3	III-A(b)	-
<i>Sophora angustifolia</i>	herb	o-pin	10-15	+	3	III-A(b)	-
<i>Styphnolobium japonicum</i>	arb	o-pin	6-8	+	3	III-A(b)	+
<i>Cladrastis lutea</i>	arb	o-pin	3-4	+	5	III-A(a)	-
<i>Platyosprion platycarpum</i>	arb	o-pin	4-7	+	3	III-A(b)	+
<i>Maackia amurensis</i> var. <i>Buergeri</i>	arb	o-pin	3-6	+	3	III-A(b)	+

PODARYLIEÆ

<i>Thermopsis fabacea</i>	herb	pal	(3)	+	3	III-B(a)	+
<i>Baptisia australis</i>	herb	pal	(3)	-	3	III-B(a)	+

GENISTEÆ

<i>Crotalaria sessiliflora</i>	herb	s	(1)	-	3	II-C(a)	-
<i>C. usaramoensis</i>	frut	pal	(3)	+	3	III-B(b)	+
<i>Lupinus hirsutus</i>	herb	pal	(5-15)	-	3	II-B(b)	-
<i>L. luteus</i>	herb	pal	(5-11)	-	3	II-B(a)	-
<i>Genista anglica</i>	frut	s	(1)	-	1	I	-
<i>G. germanica</i>	frut	s	(1)	-	1	I	-
<i>G. pilosa</i>	frut	s	(1)	-	1	I	-
<i>Laburnum vulgare</i>	frut	pal	(3)	+	3	III-B(b)	+
<i>Ulex europæus</i>	frut	s	(1)	-	1	I	-
<i>Cytisus Scoparius</i>	frut	{ s pal }	{ (1) (3) }	-	1	I	-

TRIFOLIEÆ

<i>Medicago denticulata</i>	herb	o-pin	1	—	3	III-B(b)	—
<i>M. sativa</i>	herb	o-pin	1	—	3	III-B(b)	—
<i>Melilotus suaveolens</i>	herb	o-pin	1	—	3	III-B(b)	—
<i>Trifolium Lupinaster</i>	herb	pal	(3-5)	—	3	II-A(a)	—
<i>T. repens</i>	herb	pal	(3)	—	3	II< ^{A(a)} _[C(a)]	—
<i>T. pratense</i>	herb	pal	(3)	—	3	II-A(a)	—

LOTEÆ

<i>Lotus corniculatus</i> var. <i>japonicus</i>	herb	pal	(3)	—	3	II-B(a)	—
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GALEGEÆ

<i>Indigofera Dosua</i>	frut	o-pin	6-10	+	3	III-C(b)	+
<i>I. incarnata</i>	frut	o-pin	6-8	+	3	III-A(b)	—
<i>I. Kirilowii</i>	frut	o-pin	3-6	+	3	III-A(b)	—
<i>I. pseudo-tinctoria</i>	herb	o-pin	4-6	+	3	III-C(b)	+
<i>Amorpha fruticosa</i>	frut	o-pin	5-10	+	3	III< ^{A(b)} _{C(b)}	+
<i>Tephrosia candida</i>	herb	o-pin	8-12	+	3	III-C(b)	+
<i>Millettia reticulata</i>	arb	o-pin	2-4	+	3	III-C(b)	+
<i>M. taiwaniana</i>	arb	o-pin	6-7	+	3	III-A(b)	+
<i>Wistaria floribunda</i>	arb	o-pin	6-8	+	3	III-C(b)	+
<i>W. japonica</i>	arb	o-pin	5-7	+	3	III-C(b)	+
<i>W. sinensis</i>	arb	o-pin	6-8	+	3	III-C(b)	+
<i>W. venusta</i>	arb	o-pin	6-8	+	3	III-C(b)	+
<i>Robinia hispida</i>	arb	o-pin	3-6	+	3	III< ^{A(a)} _{A(b)}	+
<i>R. pseudacacia</i>	arb	o-pin	4-9	+	3	III-A(b)	+
<i>Caragana Chamlagu</i>	frut	e-pin	2	—	3	III-B(a)	—
<i>Astragalus adsurgens</i>	herb	o-pin	5-10	—	3	II-B(b)	—
<i>A. reflexistipulus</i>	herb	o-pin	5-7	—	3	II-B(b)	—
<i>A. sinicus</i>	herb	o-pin	4-8	—	3	II-B(a)	—
<i>Glycyrrhiza dubia</i>	herb	o-pin	2-3	+	3	III-C(b)	+
<i>G. echinata</i>	herb	o-pin	2-3	+	3	III-C(b)	+
<i>G. foetida</i>	herb	o-pin	2-3	+	3	III-C(b)	+

HEDYSAREÆ

<i>Aeschynomene indica</i>	herb	e-pin	∞	+	3	III-A(b)	—
<i>Arachis hypogæa</i>	herb	e-pin	2	+	3	III-A(a)	—
<i>Desmodium caudatum</i>	frut	o-pin	1	+	5	III-A(b)	+
<i>D. gyrans</i>	herb	$\begin{Bmatrix} s \\ o-pin \end{Bmatrix}$	$\begin{pmatrix} 1 \\ 1 \end{pmatrix}$	+	3	III-C(b)	+
<i>D. Oldhami</i>	herb	o-pin	1-3	+	5	III-A(b)	+
<i>D. podocarpum</i> var. <i>indicum</i>	herb	o-pin	1	+	$\begin{Bmatrix} 3 \\ (4, 5) \end{Bmatrix}$	III-A(b)	+
<i>D. racemosum</i>	herb	o-pin	1	+	$\begin{Bmatrix} 3 \\ (4, 5) \end{Bmatrix}$	III-A(b)	+
<i>Lespedeza Buergeri</i>	frut	o-pin	1	+	3	III- $\begin{Bmatrix} A(b) \\ C(b) \end{Bmatrix}$	+
<i>L. cuneata</i>	herb	$\begin{Bmatrix} o-pin \\ pal \end{Bmatrix}$	$\begin{pmatrix} 1 \\ (3) \end{pmatrix}$	+	3	III-C(b)	+
<i>L. nikkoensis</i>	frut	o-pin	1	+	3	III- $\begin{Bmatrix} A(b) \\ C(b) \end{Bmatrix}$	+
<i>L. pilosa</i>	herb	o-pin	1	+	3	III-C(b)	+
<i>L. serpens</i>	herb	$\begin{Bmatrix} o-pin \\ (pal) \end{Bmatrix}$	$\begin{pmatrix} 1 \\ (3) \end{pmatrix}$	+	3	III-C(b)	+
<i>L. tomentosa</i>	herb	o-pin	1	+	3	III- $\begin{Bmatrix} A(b) \\ C(b) \end{Bmatrix}$	+
<i>Kummerowia striata</i>	herb	pal	(3)	+	3	III-C(b)	+

DALBERGIEÆ

<i>Dalbergia Sissoo</i>	arb	o-pin	2-3	+	3	III-A(b)	—
<i>Pterocarpus indicus</i>	arb	o-pin	3-5	+	$\begin{Bmatrix} 3 \\ (4) \end{Bmatrix}$	III-A(b)	+
<i>Derris elliptica</i>	arb	o-pin	5-7	+	3	III-A(b)	+
<i>Pongamia glabra</i>	arb	o-pin	2	+	3	III-A(b)	+
<i>Euchresta japonica</i>	frut	o-pin	1	+	3	III-A(b)	+

VICIEÆ

<i>Vicia bifolia</i>	herb	e-pin	1	—	3	II- $\begin{Bmatrix} A(a) \\ [C(a)] \end{Bmatrix}$	—
<i>V. Faba</i>	herb	e-pin	1-4	—	3	II- $\begin{Bmatrix} A(a) \\ A(b) \end{Bmatrix}$	—
<i>V. hirsuta</i>	herb	e-pin	7-10	—	3	II-A(a)	—
<i>V. nipponica</i> var. <i>typica</i>	herb	e-pin	2-3	—	3	II-A(b)	—
<i>V. sativa</i>	herb	e-pin	5-10	—	3	II-A(a)	—
<i>V. tetrasperma</i>	herb	e-pin	4-6	—	3	II-A(a)	—
<i>V. unijuga</i>	herb	e-pin	1	—	3	II-A(a)	—
<i>Lathyrus Davidii</i>	herb	e-pin	3-4	—	3	II-A(b)	+
<i>L. maritimus</i> var. <i>glaber</i>	herb	e-pin	3-6	—	3	II-A(b)	—
<i>L. palustris</i> var. <i>linearifolius</i>	herb	e-pin	2-3	—	3	II-A(b)	—

<i>L. vernus</i>	herb	e-pin	2-3	—	3	II-A(b)	—
<i>Pisum sativum</i>	herb	e-pin	2-3	—	3	II-A(a)	—
PHASEOLEÆ							
<i>Clitoria ternata</i>	herb	o-pin	1-3	+	3	III-C(b)	+
<i>Amphicarpæa japonica</i>	herb	o-pin	1	+	3	III-A(b)	+
<i>Dumasia truncata</i>	herb	o-pin	1	+	3	III-A(b)	(+)
<i>Glycine Soja</i>	herb	o-pin	1	+	3	III-A(b)	+
<i>G. ussuriensis</i>	herb	o-pin	1	+	3	III-D	+
<i>Erythrina crista-galli</i>	frut	o-pin	1	+	3	III-D	(+)
<i>E. indica</i>	frut	o-pin	1	+	3	III-D	(+)
<i>Apios Fortunei</i>	herb	o-pin	1-2	+	3	III-A(b)	+
<i>Mucuna ferruginea</i>	arb	o-pin	1	+	3	III-A(b)	(+)
<i>M. Toyoshimai</i>	arb	o-pin	1	+	3	III-A(b)	(+)
<i>Pueraria Thunbergiana</i>	arb	o-pin	1	+	5	III-D	+
<i>Canavalia ensiformis</i>	herb	o-pin	1	+	3	III-A(b)	+
<i>C. lineata</i>	herb	o-pin	1	+	5	III-A(b)	+
<i>Rhynchosia volubilis</i>	herb	o-pin	1	+	3	III-A(b)	+
<i>Phaseolus multiflorus</i>	herb	o-pin	1	+	5	III-D	+
<i>P. angularis</i>	herb	o-pin	1	+	5	III-A(b)	+
<i>Vigna sinensis</i>	herb	o-pin	1	+	5	III-D	+
<i>V. sinensis</i> var. <i>Catjang</i>	herb	o-pin	1	+	5	III-D	+
<i>Dolichos Lablab</i>	herb	o-pin	1	+	5	III-A(b)	+

PART III. RÉSUMÉ.

1. In the present paper the vascular system in nodal region, leaf-base, petiole, and rachis have been traced, illustrated by 133 species belonging to the subfamilies *Mimosoideæ*, *Cæsalpinioidæ*, and *Papilionatæ* of the family *Leguminosæ*.

2. All the investigated species of *Mimosoideæ* represent the trilacunar type of the node, and almost all of *Cæsalpinioidæ* and *Papilionatæ* as well. The unilacunar type is found in a few closely related genera of *Papilionatæ*, while the multilacunar type appears in genera far apart in the natural systematic groups among the *Cæsalpinioidæ* and *Papilionatæ*; and though the number of gaps is five in most species, there are even found cases of seven and nine gaps. The gradual transition between the trilacunar and multilacunar types is observed.

3. Stipular traces are always supplied from the lateral foliar trace situated far from the median one and independent of the number of traces for the stipule. When the foliar trace shows a form of an open arc or a bar in transverse section, the traces are derived in many cases from the outer end, and when it is of a form of a deeply-curved arc or a ringlet, the traces usually issue from the portion more or less apart from the outer margin of the foliar trace, or from the corresponding portion in the case of a ringlet.

4. The basal sheathing and the cavity for the intra-petiolar bud, and the vascular system in these regions is briefly stated.

5. The vascular system in the basal and slender parts of the petiole is roughly divided, for the convenience sake of grouping, into three types; I, II, and III.

6. As Type I, the case with a single foliar trace is chosen. The topographical disposition of the petiolar bundle is given by formula (1).

7. Type II contains the case in which the foliar traces which keep more or less apart from one another, are, at the basal part of the petiole, connected by their branches in various ways by which the number of main bundles in the slender part of the petiole is determined. This type is widely prevalent among the herbaceous species without the pulvinus at the petiolar base. According to this mode of connection of the foliar traces at the petiolar base, this type is again divided into seven subtypes; A(a), A(b), B(a), B(b), C(a), C(b), and D. The topographical disposition of the petiolar bundles in the slender part of the petiole is given by the formulae (2), (3), and (4).

8. Type III is the case in which the foliar traces are, at the petiolar base, fused into a continuous arc or ring. The species belonging to this category are mostly characterized by the possession of a more or less marked pulvinus. Preceding to divide this type into several subtypes, the following respects are considered.

(a) The modes of fusion at the petiolar base—considering also the presence or absence of the medullary bundles and the invagination on the ventral side of the stele—are divided into four cases—(α), (β), (γ), and (δ).

(b) The stele in the pulvinus shows, almost always, the most converged portion. The relative size of diameters at the middle of the pulvinus, at the transitional region between the pulvinus and the slender part of the petiole, at the middle of the petiole, and those of the stele in the above-mentioned regions, are shown with a table.

(c) The topography of the petiolar bundles in the slender part of the petiole is given, besides the formulae (2), (3), (4) in Type II, by the formulae (2)', (3)', (4)', (5)_{a-c}, (5)'. The cases in which there is a more or less marked invagination on the ventral side of the stele, or conditions closely related to this, and the case of phyllode, are specially treated.

In considering the combination of the various conditions in (a) and (c) just stated, Type III is divided into the subtypes; A(a), A(b), B(a), B(b), C(a), C(b), D, E, F(a), F(b), and G.

9. The relationships among the types thus considered and the distribution of these types among the natural systematic groups are considered.

10. These types are compared with those determined by previous investigators.

11. The presence or absence of the ridge bundles is very irregular even in one and the same genus. In usual cases, they are separated from the petiolar stele at the transitional region between the pulvinus and the slender part of the petiole.

(a) In *Mimosoideæ*, the ridge bundles depart from the widely separated—generally two—portions of the ventral side of the vascular ring or circle at the transitional region, and between these two points of departure, there remains a large bundle.

(b) In *Papilionatæ*, there remain, if present, either a single or a couple of feeble segments.

(c) In *Cæsalpinioidæ*, both manners of departure of ridge bundles are found.

12. The ridge bundles in the slender part of the petiole continue through the whole length of the rachis in some species, while, in others those in the internodes occur independently at each nodule. Some other modes of behaviour of the ridge bundles, some exceptional cases, and the conditions of the nodule having close relationship with the ridge bundles, are considered.

13. The vascular system above the petiolar top in various leaf-types are respectively discussed, and the relationship among those briefly considered.

14. Finally, some external-morphological and vascular-anatomical features in each species are summed up in a table.

* * * *

In closing I wish to offer my heartfelt thanks to Professor Y. OGURA, who furnished me with many wholesome advices and invaluable criticism throughout this investigation. I would also express my thanks to Mr. M. KUMAZAWA, now Professor of the Fourth High School, Mr. H. TOYOSHIMA of the Bonin Administration, Mr. N. MATSUZAKI of the Botanic Garden of Tokyo Imperial University, Mr. N. MOCHIZUKI of the Nikko Botanic Garden, Mr. K. HISAUCHI, and Messrs. H. ITO, F. MAEKAWA, and Y. MOMIYAMA, of our Botanical Institute, who have all offered me much valuable help in one way or another. Finally I must express my gratitude to Professors K. SHIBATA and T. NAKAI for facilitating the publication of this paper.

September 10, 1933.

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EXPLANATIONS OF PLATES.

(Except Pl. VIII. fig. 50, all figures are shown by transverse sections.)

PLATE V.

- Fig. 1. *Cæsalpinia Bonducella* FLEM. Section through the node, an example of the multi-lacunar node. Seven foliar traces are seen. ($\times 6$)
- Fig. 2. *Cytisus Scoparius* LINK. Sections through the node showing an unilacunar node. A large foliar trace has just departed from the vascular cylinder of the stem. Prominent ridges in the stem are seen. ($\times 35$)
- Fig. 3. *Desmodium racemosum* DC. Middle of the pulvinus. The stele representing a continuous ring is converged into a small area compared to that of the pulvinus. ($\times 20$)
- Fig. 4. *Mimosa pudica* L. The same. ($\times 20$)
- Fig. 5. *Erythrina crista-galli* L. Middle of the pulvinus showing the medullary bundles within the continuous ring. ($\times 35$)
- Fig. 6. *Bauhinia alba* BUCH.-HAM. Basal part of the pulvinus having a pair of small bundles in the concavity of a continuous arc. ($\times 40$).
- Fig. 7. *Tamarindus indica* L. Middle portion of the pulvinus. An amphivasal concentric bundle is surrounded by a continuous ring. ($\times 60$)
- Fig. 8. *Tamarindus indica* L. Middle portion of the petiole. On the ventral portion of the stele, a slight invagination is seen. ($\times 40$)
- Fig. 9. *Bauhinia purpurea* L. Middle portion of the petiole showing the invagination on the ventral side of the stele and a medullary bundle. ($\times 40$)
- Fig. 10. *Bauhinia japonica* MAXIM. Middle portion of the petiole. An amphivasal medullary bundle is surrounded by a ring. ($\times 35$)

- Fig. 11. *Cercis canadensis* L. Middle portion of the petiole. A dorsal ellipse and a ventral ringlet are seen. ($\times 20$).
- Fig. 12. and Fig. 13. *Cercis chinensis* BUNGE. Middle portion of the petiole showing two cases. In fig. 12, a small ringlet on the ventral and a continuous ellipse on the dorsal become continuous, at the left hand, about to transform from the condition represented in fig. 11 into the condition shown in fig. 13, in which an amphivasal ringlet is surrounded by an outer ring. ($\times 25$)

PLATE VI.

(Except Fig. 24, all figures represent the middle portion of the petiole.)

- Fig. 14. *Desmodium racemosum* DC. ($\times 35$)
- Fig. 15. *Lespedeza Buergeri* MIQ. ($\times 45$)
- Fig. 16. *Dumasia truncata* SIEB. et ZUCC. ($\times 45$)
- Fig. 17. *Mucuna ferruginea* MATSUM. ($\times 25$)
- Fig. 18. *Indigofera incarnata* NAKAI. ($\times 40$)
- Fig. 19. *Vicia Faba* L. A case having relatively numerous leaflets, showing a few minute bundles on the ventral side. ($\times 17$)
- Fig. 20. *Vicia unijuga* AL. BR. ($\times 17$)
- Fig. 21. *Arachis hypogaea* L. ($\times 25$)
- Fig. 22. *Euchresta japonica* BENTH. ($\times 30$)
- Fig. 23. *Ormosia formosana* KANEHIRA. A few secretory cavities are seen on the periphery. ($\times 50$)
- Fig. 24. *Ormosia formosana* KANEHIRA. Middle of a higher internodule. ($\times 50$)
- Fig. 25. *Lupinus hirsutus* L. ($\times 12$)
- Fig. 26. *Crotalaria usaramoensis* E. G. BAKER. ($\times 40$)

PLATE VII.

(All figures, except fig. 36, are shown the middle of the petiole.)

- Fig. 27. *Caragana Chamlagu* LAM. The bast sheaths are well-developed. ($\times 45$)
- Fig. 28. *Thermopsis fabacea* DC. ($\times 40$)
- Fig. 29. *Lespedeza tomentosa* SIEB. ($\times 45$)
- Fig. 30. *Tephrosia candida* DC. ($\times 25$)
- Fig. 31. *Mimosa pudica* L. ($\times 50$)
- Fig. 32. *Pithecolobium dulce* BENTH. ($\times 50$)
- Fig. 33. *Albizia Julibrissin* DURAZZ. ($\times 25$)
- Fig. 34. *Acacia villosa* WILLD. ($\times 35$)
- Fig. 35. *Bauhinia alba* BUCH.-HAM. ($\times 40$)
- Fig. 36. *Pongamia glabra* VENT. Higher part of petiole showing the departure of a pair of small bundles from the ventral side of the vascular cylinder. ($\times 70$).

PLATE VIII.

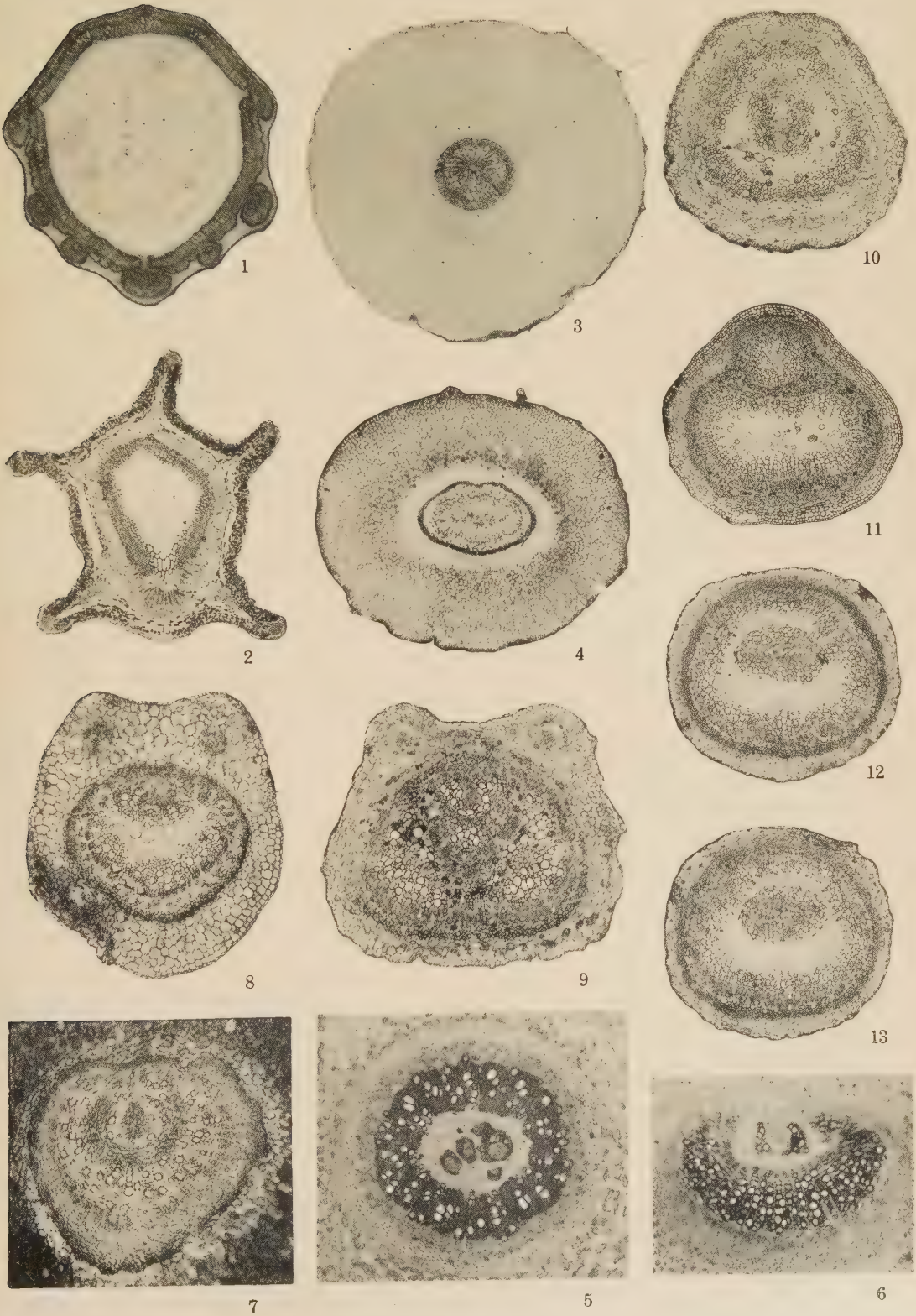
- Fig. 37. *Mimosa pudica* L. The transitional region between the pulvinus and the slender part of the petiole showing the departure of the ridge bundles. ($\times 40$)
- Figs. 38 and 39. *Robinia pseudacacia* L. Successive levels of the transitional region between the pulvinus and the slender part of the petiole showing the departure of the ridge bundles. ($\times 40$)
- Figs. 40 and 41. *Cercis canadensis* L. Sections through the petiolar top, showing the changes in the disposition of the bundles. ($\times 25$)
- Figs. 42 and 43. *Bauhinia alba* BUCH.-HAM. Sections through the petiolar top, showing the changes in the disposition of bundles. ($\times 20$)
- Figs. 44, 45, and 46. *Lupinus hirsutus* L. Sections through the petiolar top showing the vascular system in this region. ($\times 10$)
- Figs. 47, 48, and 49. *Acacia confusa* MERR. Fig. 47, lower part of the pulvinus. Fig. 48, the transitional region between the pulvinus and the phyllodial petiole. Fig. 49, lower part of the phyllode. ($\times 25$)
- Fig. 50. *Pueraria Thunbergiana* BENTH. Bilobed stipule from the surface showing the veinlets issued from a vascular circuit, upper half of which is a part of a lateral foliar trace. ($\times 5$)

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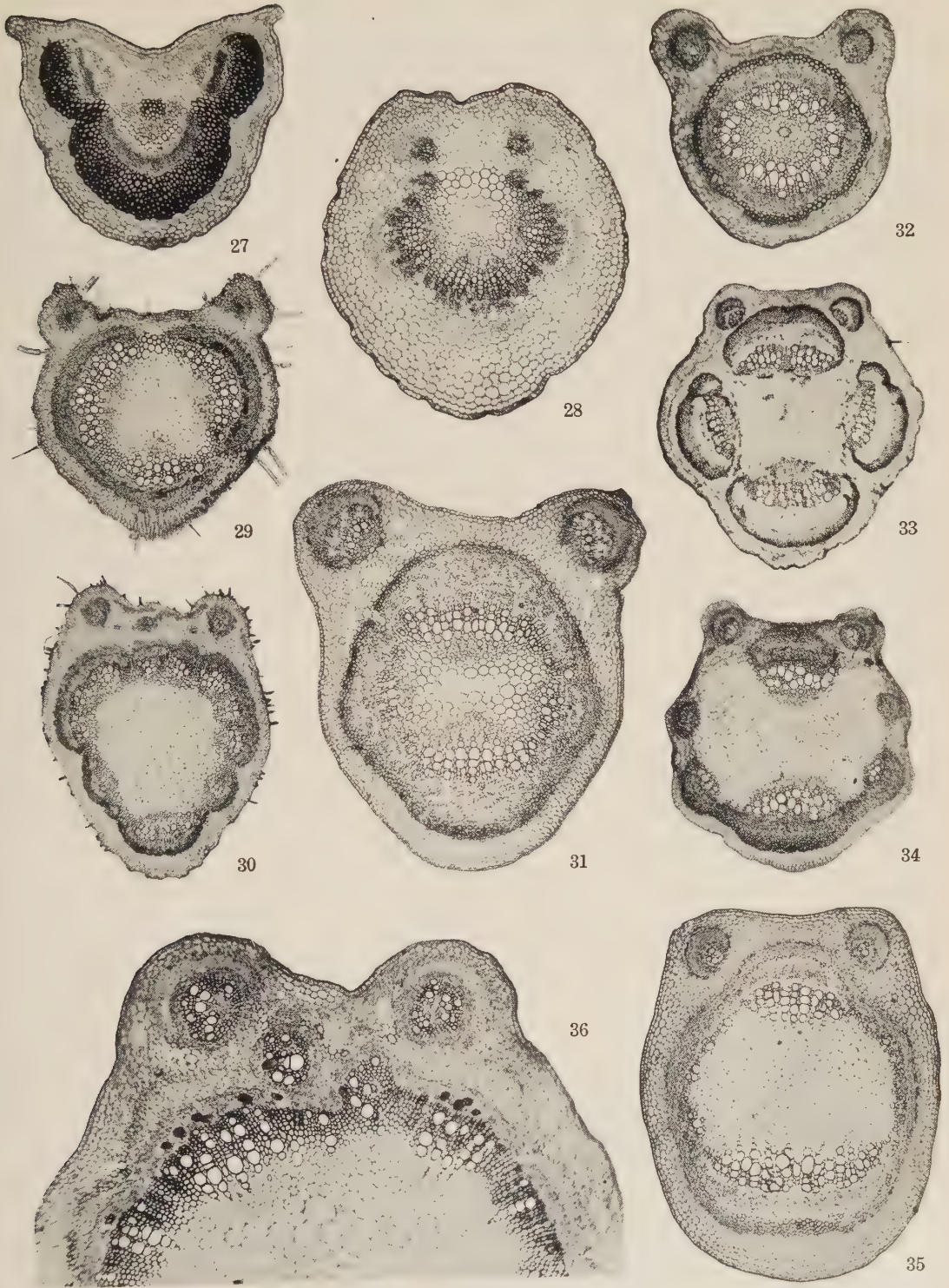
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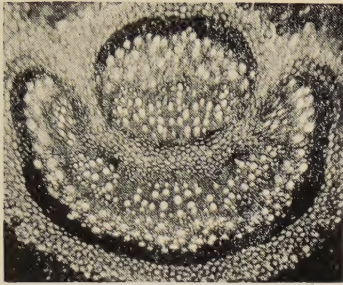
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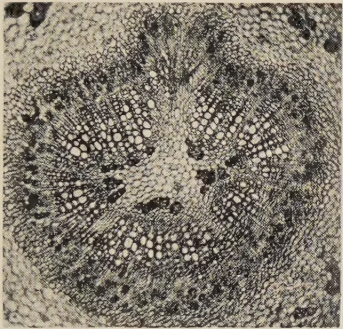




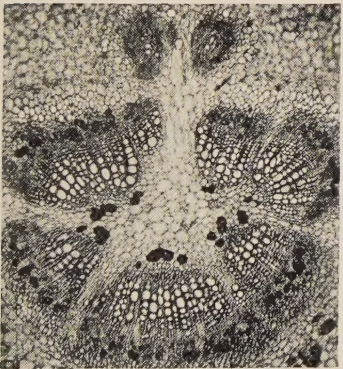




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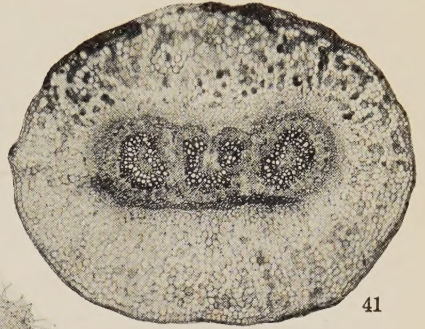
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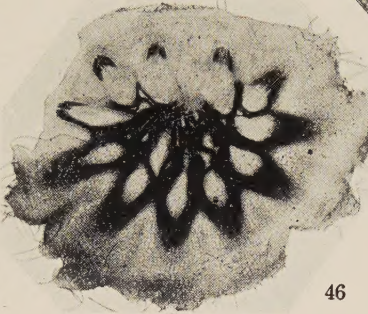
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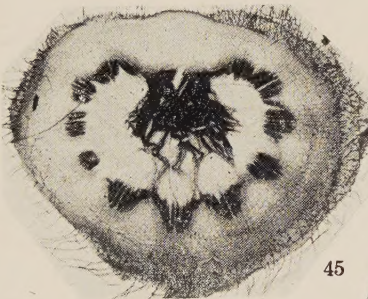
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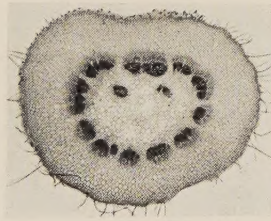
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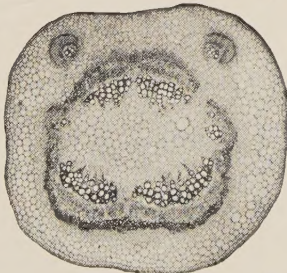
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